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MUNICIPAL NOTES IN SWITZERLAND AND GERMANY.

(Editorial Correspondence.)

The Continental engineers whom I have met have given me a most hearty welcome, and have done everything in their power to make my visit both pleasant and profitable. I was scarcely in my hotel at Zurich before I received a telephone message from Prof. Karl E. Hilgard, M. Am. Soc. C. E., of the Polytechnic School, saying that he would call on me in twenty minutes. He spent one whole day with me, introducing me to a number of city officials and going with me on most of my visits to municipal works. Other Continental engineers have been equally courteous and painstaking. I have great pleasure in saying that the attention shown me is in large measure a tribute to the esteem in which these European engineers, chemists and biologists hold their fellow-workers in America through whom I was generally provided with letters of introduction. Besides, some of the gentlemen whom I have met have themselves been in America and speak in glowing terms of the reception there given them; while Professor Hilgard, as many of our readers know, is an American citizen, and was formerly Engineer of Bridges and Buildings on the Northern Pacific Ry. He now teaches a number of branches of civil engineering at the Polytechnic.

ZURICH, THE GROSSMÜNSTER, THE RIVER LIMMAT, LAKE ZURICH, AND THE ALPS; LOOKING SOUTH.

WHAT NATURE AND MAN HAVE DONE FOR ZURICH.

Nature has done much for Zurich, providing her with beautiful lake and mountain scenery, pure air, and an abundant supply of water; and the city government has conserved and supplemented the gifts of nature. I will not attempt to describe the scenic beauty of the city, the charm of the distant Alps and of the nearer vine-clad hills which surround the lake at whose mouth the city lies, and the attractions of the rapid-flowing Limmat, which serves as an outlet to the lake and furnishes, from its numerous quays and bridges, a series of vantage points for seeing many of the quaint and interesting buildings with which this city abounds. A partial conception of these features may be gained from the illustrations which accompany this letter. Of these the first needs no explanation. The second is taken from the west side of the river, farther to the north than the first one, and near the principal railway station. The fine architectural character of the two bridges shown in these views is worthy of attention. Crowning the second view is the Polytechnic School. The third view, taken from the east, shows the Stadt-haus, or City hall. This building has a large, well-lighted interior court, with galleries giving access to the rooms on the second floor, and with ample wall space, decorated at the two ends with large paintings of adjacent portions of the city as they looked some centuries ago. All three views show stretches of the substantial quays, constructed at no little expense.

Above the second bridge shown in the first view the lake spreads out on either side. Each shore for some distance is preserved to the public, the reservation terminating on the west side in Belvoir Park, and on the east side in zoological gardens. There is still another park a short distance below the bridge shown in the second view, which utilizes the triangular space at the junction of the tributary River Sihl with the Limmat.

It will be seen from the views and the foregoing notes that the city has taken great pains not to mar the beauties of nature by engineering works out of harmony therewith; that it has preserved and improved its waterfront for the benefit of the public, and that, although surrounded by scenery of unusual majesty and beauty, it has nevertheless developed parks and gardens for the more intimate enjoyment of the people.

The scenic features of Zurich having been reviewed, we pass on to some of the more material phases of the city and its public works. The population of Zurich is about 160,000. The city owns its water-works and its gas and electric lighting plants, and is rapidly acquiring possession of the electric street railways. The water supply is taken from the lake and subjected to double filtration. The main features of the filter plants and the chemical and bacterial results obtained were set forth in Engineering News of April 28 (p. 402), and I will only add that the "fore-filters" or preliminary filters are practically mechanical filters, rectangular in plan, operated without a coagulant and employing compressed air for agitating the sand while it is being washed.*

A twelve-cell Horsfall refuse destructor has just been put in operation at Zurich. Among the interesting features of the plant are an electric overhead traveling crane for lifting the boxes from the collecting wagons and dumping them on the tipping platform; an electric-driven fan for forced draft; two boilers for utilizing the heat from the destructors, and an electric generator driven by a 220-HP. steam turbine supplied from the boilers. All electric current not needed at the destructor will be delivered to the electric light and power plant owned by the town. An interesting adjunct to the refuse destructor plant is a handsome 5-story brick apartment house, built by the city, with seven sets of apartments for families and separate rooms for single men, all to be rented to the employees at the refuse destructor.

The sewage of Zurich is discharged, untreated, into the River Limmat, below the town, but a pail system is used for excluding the solid part of the excreta from the sewers.

A large, well-equipped disinfecting station was completed at Zurich early in the present year. Of it and of some other phases of disinfection I

*The original slow-sand filters at Zurich were described in Engineering News, Vol. July-Dec., 1894, p. 35, in an illustrated article by Prof. Wm. P. Mason, of Troy, N. Y. The preliminary rapid or mechanical filters were described in detail by Prof. Karl E. Hilgard in Trans. Am. Soc. C. E., Vol. 44, p. 425.

hope to write later. The plans for the station were made by Mr. Mettler, Inspector of Public Health, to whom, and also to Mr. Gluck, his superior officer, I am indebted for courtesies shown in visiting the refuse destructor, the station for the reception of night soil, and the disinfecting station.

While in Zurich I met Mr. Wm. E. Mott, Assistant Professor of Hydraulic Engineering at Cornell University, and Mr. Winslow Herschel, son of Mr. Clemens Herschel, M. Am. Soc. C. E., of New York, and recently on the staff of the New York Water Supply Commission. Professor Mott is utilizing a year's leave of absence from Cornell in study at the Zurich Polytechnic. Mr. Herschel is dividing his time between that institution and the works of Escher, Wyss & Co., in Zurich.

BRIDGE NEAR THE MAIN RAILWAY STATION, WITH A PART OF THE ZURICH POLYTECHNIC SCHOOL AT THE TOP OF THE HILL; LOOKING SOUTHEAST.

A BRIEF STOP IN CARLSRUHE.

After a grand ride from Zurich by way of the Falls of the Rhine and the Black Forest, I reached Carlsruhe, where I stopped to see Dr. Hans Bunte. Dr. Bunte is a most genial man, and he must be a very busy one also, for besides teaching chemical technology to some 300 students, he is editor of the technical journal known in English as the Journal of Gas Lighting and Water Supply, and secretary of the German Gas and Water Association.

The Technical High School, I judge, is similar to one of our American technical schools. It is now attended by about 1,500 students. I met here Prof. Emil Kohler, of the civil engineering department, and saw his hydraulic laboratory, which includes a steel tank some 10 × 60 ft. × 3 ft. deep for making studies of stream erosion, dams, and the like.

I was particularly interested in the Fête Hall of the school, a large hall for use on special public occasions, decorated with a number of allegorical paintings and many portraits of eminent scientists.

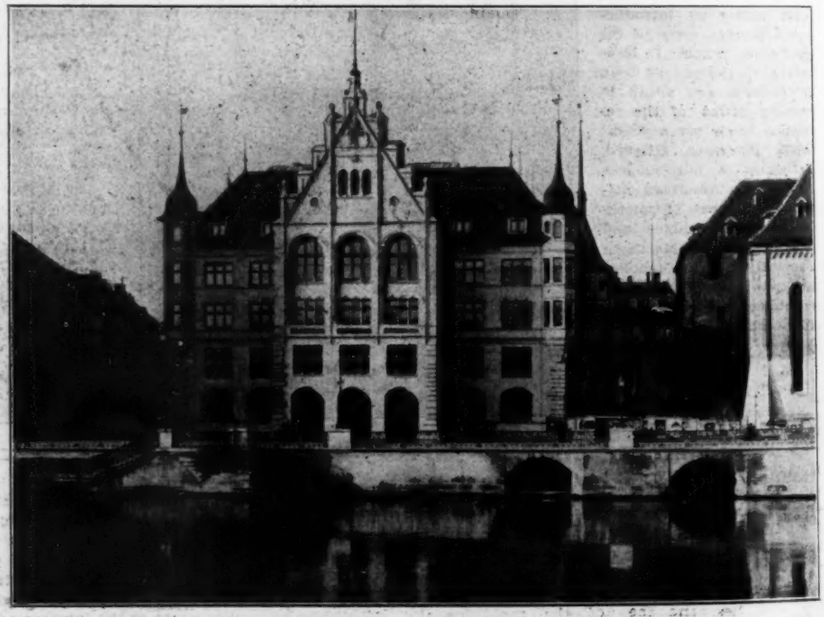
I gathered from Dr. Bunte and from others as well that ground water supplies are rapidly growing in favor and frequency of utilization in Germany, and that attention is concentrated on the purification of such surface water as is actually used for public purposes rather than on maintenance of the purity of streams in general by insisting on preliminary treatment of sewage deposited in them. I do not mean by this, however, that the pollution of public water supplies is winked at. I have also been informed from other than German sources that Emperor William is behind the movement for ground water supplies, and that, during a typhoid fever outbreak in some German city, he sent a fiery telegram taking the authorities to task for permitting conditions which made such an outbreak possible.

The so-called bacterial treatment of sewage, Dr. Bunte said, has made scarcely any headway in Germany.

As to Carlsruhe itself, I had an opportunity to make only a few general observations. Perhaps the most interesting feature of the city is its street plan. In general, all streets either radiate from the castle of the Grand Duke of Baden, or are concentric with the circular public place in front of the castle.

FRANKFORT-ON-THE-MAIN.

To many American engineers the name of Mr. W. H. Lindley* is very familiar. As city engineer of Frankfort from 1884 to 1896, and in his private practice throughout a wide range of territory, Mr. Lindley has done a large amount of important engineering work. In his absence I was received and greatly assisted at Frankfort by Messrs. H. Streng* and I. W. English,* his principal assistant engineers. Mr. Streng spent one entire day in my behalf, first introducing me to city officials and securing permits and then visiting public works.



THE CITY HALL, ZURICH, LOOKING WEST ACROSS THE LIMMAT.

The formalities incident to visiting municipal works in some English cities were missing compared to what Mr. Streng and I went through in Frankfort in order to gain admission to various parts of the water- and sewage-works. For each permit I had to sign a statement to the effect that I would not hold the city responsible for any accident that might befall me in visiting the works in question, and that I would reimburse the city for any damage I might do to the said works. I gladly add, however, that, formalities having been observed, great pains were taken by the various officials and caretakers to enable me to see everything. As an example, several hundred candles were lighted to facilitate my passage through an underground gallery 1,000 meters in length, containing a suction main connected with an underground water supply.

Frankfort has a double system of water supply: Water is taken from the River Main for various street purposes and for watering lawns and gardens, while the potable water is either brought from mountain springs some 60 miles distant, or is pumped from wells. The wells, of which there are three groups, are located in a public forest and were sunk in the driest of dry land, which gave absolutely no indication of water-bearing strata beneath. Two of the three groups of wells were developed by Mr. Lindley and the other group by his successor. In visiting the various pumping stations and wells, I had the pleasure of driving for many miles through an old forest which is now conducted on scientific lines. In my railway journeys on the continent, also, I have seen hundreds of miles of forest under intelligent supervision, with their numerous ditches, paths, roads, and clearings to lessen the danger of fires and the careful clearing up of all brushwood for the same purpose and also to utilize every cubic inch of wood. In most parts of America the time has not yet come when it would pay to utilize all the parts of every tree cut down, to the smallest twig, but in every section it would pay to take immediate steps for a more intelligent protection against forest fires.

The sewage of Frankfort was formerly treated chemically. Strange to say, the Imperial authorities first ordered or permitted the use of chemicals to be discontinued and recently, I am told, it has ordered the period of sedimentation to be cut in half by dividing each old tank into two equal parts. The reason given for these changes is

*29 Bliithersdorfplatz, Frankfort-on-the-Main, Germany.

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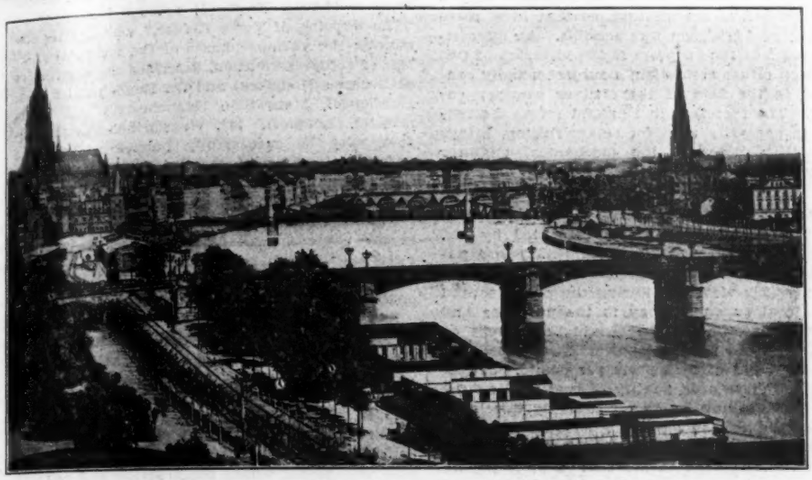
that the volume of the River Main is sufficient to dilute the sewage after partial clarification. Moreover, it appears that the capacity of the works had been exceeded by the increased volume of sewage, for besides cutting the tanks in half, and otherwise changing them, new ones are now being built. Both the old and new tanks are underground, with division walls supporting piers and arches from which domes were turned to form the roof. All the masonry is of brick, of heavy section and handsome construction.



BRIDGES ACROSS THE RIVER MAIN, BETWEEN FRANKFORT AND SACHSENHAUSEN.

(The arched masonry bridge in the distance is many hundred years old. To the left and in front of it is the Dom or Cathedral.)

On returning from our long drive to the wells in the forest and to the sewage works, we crossed over an arched masonry bridge many hundred years old. One of the accompanying illustrations shows this bridge in the distance and another shows a comparatively recent (1843) statue of Charlemagne which ornaments the bridge. Both of these views show recent examples of good bridge architecture at Frankfort.

THE OZONE PLANT AND OTHER INTERESTING WORKS AT WIESBADEN.

I went to Wiesbaden, which is only an hour's ride from Frankfort, intending to remain but two or three hours, but I was so well received and offered such an enticing program that I spent the whole day there. I owe the pleasure and instruction of that day to Mr. H. P. N. Halbertsma, Director of the City Water, Gas and Electric Works.

I cannot begin to record here all I saw in that day, but I must give an outline of the latest information regarding the plant erected here by Siemens & Halske, of Berlin, for the treatment of water by ozone. This plant was not in operation at the time of my visit, and is now held in reserve for the treatment of a portion of a supplementary ground water supply from wells near the Rhine at such times as the water shows an unduly high number of bacteria. It appears that the physicians of Wiesbaden, and others interested in its reputation as a health resort, objected to the use of this ground water without some treatment, believing that it was sure to be polluted from the Rhine. There seems, however, to be little, if any, ground for this belief, unless it be at times of high water when the land above the wells is flooded. At such times the use of the wells may be discontinued or the ozone plant started. The underground water contains iron and a plant for its removal is to be installed. At present the well system is being extended, as is also an interesting system of tunnels for developing water in the mountains above the city. I conclude from what I learned at Wiesbaden and elsewhere that ozone treatment of water is still too complicated and expensive a process to be employed except in rare cases.

Wiesbaden, like Frankfort, has a dual water supply, and unlike Frankfort it has a universal meter system. Knowing of my interest in sewage works, Mr. Halbertsma took me to the plant for the treatment of the Wiesbaden sewage. Here, as at Frankfort, a long delay was occasioned to secure a formal authorization for a stranger to enter the works, which, in this case, was finally obtained over the telephone. Once inside the works, I found that the sewage was being clarified by screening and sedimentation, some of the screens being stationary and some movable, and the latter being different from any I had seen before. Sedimentation was effected in both channels and reservoirs. The effluent is discharged through a small stream into the Rhine. It was by no means clean water, but the several screenings, including one through fine meshes, and the sedimentation had removed all the grosser impurities. Of these works and some of the others at Wiesbaden and elsewhere mentioned in this letter, I hope to write more hereafter.

CONTINENTAL SLEEPING CARS.

I ran counter to the advice of friends by taking sleeping cars several times on the continent. In every case I found them more satisfactory than I had expected, and the night spent in riding from Frankfort to Hamburg was the most comfortable one I ever experienced on a sleeping car. First of all, I undressed in a private compartment, small though it was, instead of half stripping in the long central aisle of an American sleeper, having my toes stepped on meanwhile, and finishing the process by means of sundry strange gymnastic exercises in my berth. Next I had both a small window below and a handy ventilator above which I could control to my own satisfaction without regard to the temperament of fellow passengers. Finally I had, in my own compartment, all necessary toilet facilities for cleanliness and convenience. The whole compartment was a very few inches more than 4x6 ft. in dimensions. Lying at right angles instead of parallel with the axis of the car seemed an agreeable change. Obviously such sleepers are better suited to short distances and exclusively night traffic than to combined day and night service.

What I saw after my arrival in Hamburg must be reserved for another communication.

M. N. B.

Hamburg, Germany, May 13, 1904.

STATUE OF CHARLEMAGNE ON OLD MASONRY BRIDGE AT FRANKFORT-ON-MAIN.

JOINT MEETING OF THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS AND THE BRITISH INSTITUTION OF MECHANICAL ENGINEERS AT CHICAGO.

The present summer's bull movement in international amity among engineers began with a rush in the past week. Mechanical engineers of England met with mechanical engineers of America in joint meeting at Chicago—it was not a mere case of holding simultaneous meetings in the same city and coming together in the social intervals between sessions, but a complete alloying of the two societies for the time being. They met together under the alternate chairmanship of the American and the English presidents, listened to the same papers, now that of an American, now that of an English author, and took part together in the discussion.

At times, perhaps, the balance was out, one way or the other; but if the Americans had nothing to say about refuse disposal, in return the Englishmen were silent when power plants for office buildings came up for discussion. A climax was reached at the Thomas concert on the evening of the last day of the meeting, when to the strains of the respective national anthems, which are the same, the entire assembly rose and sang together—first the American and then the English words.

The attendance was very large. Nearly a thousand persons registered, and of these, the

visitors from England numbered about one hundred. Ladies and guests, of course, are included in these figures; the number of ladies was large enough to make the meeting unusually successful socially. An essential contributing factor, too, was the thoroughness and promptness with which every element of the week's entertainment was managed. Thus, it is rare and difficult for a meeting of this kind to begin its sessions promptly, and still more so to end them promptly; yet both of these feats were accomplished. The efficiency of the local committee, headed by Mr. R. W. Hunt, was mainly responsible for the successful management. The meeting was blessed with fine weather throughout, and all the excursions and sight-seeing trips were greatly enjoyed.

To give the incidents of the meeting in brief: Headquarters were established at the Auditorium Hotel, and two of the professional sessions were held here. Two sessions were held in the Fine Arts Building, adjoining the hotel, and one at Lewis Institute. The opening session was held on Tuesday evening, May 31; Comptroller McGann, of the city of Chicago, representing the Mayor, welcomed the members to the city, and the presidents of the two societies, Mr. Ambrose Swasey of Cleveland, O., and Mr. J. H. Wicksteed of Leeds, England, spoke in acknowledgment. On the following day two professional sessions were held, morning and evening, and one session was held on each of the following days, bringing the meeting to its close Friday noon, June 3. Excursions and entertainment occupied all the remaining time from Tuesday to Friday.

The excursions and technical visits comprised a trip through the tunnels of the Illinois Tunnel Co. and the same company's automatic telephone exchange; a visit to the South Chicago works of the Illinois Steel Co., where the open-hearth and Bessemer plants and the plate and rail mills were inspected; a visit to the packing plants of Swift & Co. and Armour & Co. in the stock yards; a trip down the drainage canal and to the clearing yards of the Chicago Union Transfer Railway Co., and a visit to the new steam-turbine generating station of the Chicago Edison Co. at Fisk St., where two 5,000-KW. Curtis turbines driving three-phase 9,000-volt generators, were seen in operation. The two principal social events of the meeting were a reception at the Art Institute and a concert by the Theodore Thomas Orchestra at the Auditorium Theater, both of which were very largely attended. In addition, the ladies of the party were entertained by drives, receptions, luncheons, etc.

The business part of the meeting was restricted to a minimum. At the opening session, President Swasey announced that the Council has unanimously elected Prof. John A. Sweet to honorary membership in the American Society of Mechanical Engineers. Secretary Hutton related in detail what has been done up to the present toward the construction of the Union Engineering Building in New York City, and stated that the work of clearing the site would probably begin within a month. Mr. F. J. Miller (New York, N. Y.) offered an amendment to the constitution, changing the paragraph which regulates the manner in which the constitution may be amended. At present every amendment proposed must be submitted to preliminary letter ballot, and if at least 20 members favor it, it must, after discussion at an annual meeting, be again submitted to letter ballot. Mr. Miller's amendment aims to secure a preliminary vote upon any amendment as soon as it is proposed, and only if at least twenty votes are cast in its favor shall it be submitted to letter ballot. After brief comments by Mr. R. H. Soule (New York, N. Y.), the amendment was laid over for letter ballot in accordance with the present rules.

The professional proceedings of the meeting differed from those of other meetings in that the papers were written by request, certain subjects being selected, and prominent workers in the respective fields asked to prepare papers upon them. The object was to secure a summary of present practice, American and English, in certain fields in which particular interest or activity is being manifested at present. The result has not proved altogether excellent, as may appear to some extent from the following brief report upon the papers and discussion. The discussion itself appears to have been affected unfavorably by the fact that none of the papers were received in time for distribution, "thirty days in advance of that meeting," as the rules require. In fact, the printed papers reached the members only a few days before the meeting, so that little careful study and criticism was possible. An interesting feature of the program is the inclusion of two papers on refuse cremation, a subject usually considered in the field of the civil or sanitary engineer. The fact that in England refuse distructors are generally used for steam raising, brings the matter closer to the mechanical engineer than would otherwise be the case.

THE WAGES QUESTION.

A novel and rather engaging view of the problem of paying for labor was presented by Mr. Harrington Emerson (New York, N. Y.) in a paper entitled "A Rational Basis for Wages." He introduces his view by offering the purchase and sale of coal as an analogy to the purchase and sale of labor. Coal is (or should be) bought on the basis of the potential power it contains, that is, on the basis of heat units per pound. Selling by the ton disregards quality of coal, and on the other hand, selling by power actually developed includes the efficiency of the purchaser's boiler and engine, and is therefore unfair to the seller. In direct analogy the author characterizes paying by time as being a neglect of quality of labor, and paying by output (piecework) as including the efficiency of the employer's plant. He proceeds to analyze the value of labor into three parts: (1) the value of the employee's time, (2) the value of his skill, and (3) the value of his intelligent cooperation. He would have wages divided into corresponding elements. He would pay a fixed minimum living wage for the employee's loss of liberty, and an additional amount for the workman's skill at his trade; but beyond this he would establish a third item; pay for the special value of intelligent and industrious work, as measured, for example, by the reduced time per operation in some modern systems of studying cost and time. A subsidiary suggestion made in the paper is that governments should aid in maintaining a reasonable minimum wage, by creating a demand for labor in the time of industrial depression when employment is scarce. He would have public improvements done mainly during the periods of low prices, and thereby establish a regulating condition for the labor market.

In the discussion, British engineers showed strong dissent from the author's general argument. Mr. Emerson Bainbridge (London, England) called the author's suggestions impracticable, and questioned both its premises and its conclusions. Coal is bought on quality both here and in Europe, its sulphur and ash being quite generally specified. Similarly, labor is very largely paid for according to its quality; the workman of greater skill and intelligence receives the higher wages. Mr. E. J. Chambers (Wolverhampton, England) took the position that the workman does not sell his liberty to the employer, but virtually enters into a partnership with him. The suggestion of assigning a fixed minimum wage to be paid, whether the workman was sick or well, he condemned as throwing upon the employer the burden of keeping his employees in good health. Mr. J. H. Wicksteed (Leeds, England) pointed out that the author's shrewd analogy between coal and labor finds the weak point in profit sharing; for just as selling coal by power produced would involve the efficiency of the purchaser's plant, so the workman's profit would depend largely upon the employer's equipment and managing skill. Mr. H. H. Suplee (New York, N. Y.) laid stress on the value of enthusiasm communicated from "higher up" in the shop, and offered as his ideal system the combination of good working plant, good pay for the workmen, and such enthusiasm in the management as inspires good working. Mr. Emerson, in replying, duly acknowledged the importance of proper management, instancing some cases of bad equipment and supervision as being typical of what exists in a great number of shops. He believed that in most shops 30 to 40% in cost can be saved by more intelligent supervision and management.

GARBAGE DISPOSAL BY CREMATION.

Two papers on the cremation of refuse portrayed quite thoroughly the present status of the garbage disposal problem in England. Mr. George Watson (Leeds, England) presented a paper on "The Burning of Town Refuse," which, after discussing the various phases of the technical problem of refuse cremation, describes the destructors at Brussels (Belgium) and the English cities West Hartlepool, Moss Side (Manchester) and Westminster (London). Mr. Watson believes that refuse may be successfully burned without the addition of other fuel, that it is "autocombustible" in all but exceptional cases, while in most cases the heat generated will be sufficient to be utilized for steam-raising. The four destructors described in the paper are all fitted with boilers for this purpose. The paper discussed all the factors which the engineer must consider in planning and operating a destructor plant.

The second paper, by Mr. C. Newton Russell (London, England), was entitled "Refuse Destruction by Burning, and the Utilization of Heat Generated." Its main portion is a description of the destructor plant of the Borough of Shoreditch, London, which handles the refuse from a population of about 150,000. Six Babcock & Wilcox boilers heated by twelve destructor cells compose this plant, whose construction and working results are fully described. A feature of the plant is a "thermal storage" tank, consisting for a large closed water tank mounted above the boilers and interconnected with them. In this vessel water may be heated to boiler temperature during the hours when the heat generated exceeds the load on the station. The steam, it should be mentioned, is used for generating electricity for general supply distribution in a building adjoining the destructor plant. The exhaust from the engines is used for heating purposes in a public bath and wash house built alongside the station, and for heating a library building close by. About 25,000 tons of refuse are burned per year, and some 33% of this weight is produced in clinker. The disposal of this clinker is a serious problem for a plant located in the heart of a city, since most of it must be hauled to dumps. Some of the clinker at Shoreditch is used for making concrete paving slabs, etc. Concluding, the author makes certain specific recommendations regarding destructor plants, as a result of his experience in operating the Shoreditch plant. Among these are the following:

(1) The site should, when possible, be right away from residential and important business quarters and near to a tram route and a waterway.

(2) It is unnecessary for the destructor to adjoin an electric generating station. It should, indeed, be far enough away or otherwise so placed that dust from works and clinker yard cannot reach the engine room of the generating station.

(3) Furnacemen should be made to rely on refuse as fuel; coal or coke should never be allowed inside a destructor works.

(4) About 8 to 10 tons of refuse have to be handled to produce the same amount of steam as can be got by the combustion of one ton of good coal.

(5) The use of lifts and trucks for handling refuse should be avoided where possible. Unnecessary handling of refuse soon runs up the costs. An ideal system from both a sanitary and economical point of view would be to shoot the refuse straight out of the collecting van into the furnace.

(6) Fine dust is emitted from the chimney and will prove a nuisance unless flues are well designed and cleaned right out at least once a week.

(7) Experience at Shoreditch shows that, in burning coal fires in conjunction with refuse, the full efficiency of the coal is not obtained as in an independent boiler.

Like the papers, the discussion of this subject was due to the English visitors. It was not wholly in praise of the destructor. Mr. Charles Wicksteed (Kettering, England), whose town had recently installed a refuse destructor, said there was no doubt that a destructor is a nuisance and necessarily must be so. Both smell and dust are a source of nuisance, the dust coming partly from the chimney and partly from the clinker yard. Certain kinds of refuse create a bad smell and will even make the clinker stink; such are fish and slaughter-house refuse, which must therefore

be burned at night, separate from other refuse. As a result the people living near the destructor must keep their windows closed at night. He considered the destructor problem in England as only begun to be solved, the solutions being not yet completely worked out. One or two others, however, held that English destructor practice is a thorough success. Mr. A. Saxon (Manchester, England), speaking of the destructor at Manchester, said that it was the best possible for local conditions. It has continuous grates instead of isolated cells, which latter the speaker considered not so suitable for Manchester.

STEAM TURBINES.

Four papers on steam turbines were presented to the meeting, as follows: "Some Theoretical and Practical Considerations in Steam Turbine Work," by Mr. Francis Hodgkinson (East Pittsburg, Pa.); "The De Laval Steam Turbine," by Messrs. E. S. Lea and E. Meden (Trenton, N. J.); "The Steam Turbine in Modern Engineering," by Mr. W. L. R. Emmet (Schenectady, N. Y.); and "Different Applications of Steam Turbine," by Prof. A. Rateau (Paris, France). These papers are essentially descriptions of the four styles of turbine made by the companies represented by the four authors, respectively the Parsons, the De Laval, the Curtis, and the Rateau turbine. Beyond this they contain discussions of the considerations which led to the design adopted, and one of the papers (that on the De Laval turbine) enumerates some of the troubles that have been encountered in their operation. These papers are reprinted elsewhere in this issue and need not be further noted here. It may be pointed out that Mr. Hodgkinson suggests that a desirable type of electric generator for use with steam turbines is the ordinary induction motor driven above synchronism. Such generators could not be used in all cases, but would require sufficient synchronous machinery in the system to supply the required magnetizing currents and to control the frequency of the circuit.

In the discussion, Mr. H. L. Doherty (New York, N. Y.), asked for a classification of turbines on a rational basis, in place of the heterogeneous and rather artificial classifications presented in the four papers. The request did not, however, meet with response. Prof. Storm Bull (Madison, Wis.) raised protest against the general nature of the titles under which three of the papers were presented, titles which do not indicate the fact that specific makes of turbine are described. Referring to Mr. Hodgkinson's paper, he objected to using the Pelton wheel as a starting point for developing turbine construction, as this is a special form of impulse wheel whereas most steam turbines are reaction wheels. Some tests presented in the same paper he characterized as "not made in competition," and therefore less likely to find free acceptance. He holds, also, that the phenomena of flow of steam in nozzles are not yet sufficiently understood to warrant the treatment of Mr. Hodgkinson's paper, a view which was seconded by Mr. H. H. Suplee (New York). Prof D. S. Jacobs (Hoboken, N. J.) pointed out that the economic performances reported for the various types of steam turbine ranged about the same point, differing by no greater amount than the unavoidable experimental inaccuracy. He deduces herefrom that it is futile to apply refined theory or delicate experiment to the steam turbine question, and that future development will result from practical experience and evolution. He questioned particularly Prof. Rateau's claim that the "theoretical efficiency" of his turbine is at least 20% higher than that of the Curtis type with two wheels per "cell." Mr. E. Meden (Trenton, N. J.) reported that the wear of the buckets in De Laval turbines is very slight; some buckets which had been in use for more than a year were exhibited to show that the wear is almost imperceptible. Mr. F. A. Waldron (New Haven, Conn.) stated that a very high degree of superheat is not particularly economical in turbine work, at least when economy in cost is considered. Mr. Alex. Dow (Detroit, Mich.) expressed himself as a firm believer in the steam turbine, on the ground that it is more economical in dollars and cents than the reciprocating engine. He does not believe, however, that any of the present types of turbine is a final form, but thinks that such a form must be developed from these; in eight or ten years we may have turbines as standard as Corliss engines now are. Mr. Dow deprecated the practice of requiring a condensing equipment more elaborate than the turbine itself. An expensive condensing equipment often indicates only a careless operating engineer, who is negligent in keeping his steam-system clear of air. Open heaters, which remove a large part of the dissolved air from the water, should often be used in place of closed heaters for the feed water; in one case the condenser vacuum was improved one inch by merely substituting an open for a closed heater. Further, low clearance air-pumps should be used, and care taken to keep the exhaust piping tight. Attention to such points as these will make an ultra-elaborate condensing equipment unnecessary. The subject was also discussed by Messrs. Hollis, Rockwood, Rearick and Hodgkinson.

A paper on "The Potential Efficiency of Prime Movers" was presented by Mr. C. V. Kerr (New York, N. Y.). The suggestion is offered in this paper that engine efficiency be measured by dividing the heat-equivalent of the brake horsepower by the difference in available heat of steam supplied and steam exhausted. The methods of computing such efficiencies is described and its application to a number of published engine tests is given; the computation is based on an assumed curve for the variaton of specific heat of steam with pressure. The nature of the paper makes it unsuited for more extended notice here. In discussion, Prof S. A. Reeve (Worcester, Mass.) agreed with the author as to the desirability of using the defined efficiency, though he did not approve of the name "potential efficiency." He himself has used the same efficiency for a number of years past in analyzing engine performance. Mr. F. Hodgkinson (East Pittsburg, Pa.) also objected to the term "potential efficiency" as giving no clear idea of what kind of efficiency is meant; he did not, however, offer a substitute. Mr. H. L. Doherty (New York, N. Y.) questioned whether the author's method could be applied to internal combustion engines.

POWER PLANTS OF OFFICE BUILDINGS.

The subject of "The Power Plant of Tall Office Buildings" was treated in two papers, one by Mr. J. H. Wells (New York, N. Y.), the other by Mr. R. P. Bolton (New York, N. Y.). These papers, taken together, are a concise summary of New York city practice in planning the layout and detail design of elevators, water-supply, heating and lighting of tall buildings. It is impracticable to attempt to abstract them in this place; it is worth noting, however, that in speaking of elevators the two authors took rather opposite ground. Mr. Wells inclined toward the electric elevator as being cheaper in operation; on the other hand, Mr. Bolton says

> the electric elevator has during ten years of use and improvement failed to dislodge the hydraulic system as the most reliable and suitable method of schedule operation. . . . The apparent economy of operation of an electrical system entirely disappears under analysis of these conditions, and the electric elevator stands to-day an economic failure for schedule service, while in point of simplicity, safety, ease of maintenance and control, the hydraulic elevator has maintained its reputation.

In discussion, Mr. W. H. Bryan (St. Louis, Mo.) asserted that practice in cities west of New York would not be found to justify Mr. Bolton's severe condemnation of the electric elevator. In St. Louis there are many buildings 12 to 16 stories high where electric drum elevators are working very successfully at car speeds as high as 350 to 400 ft. per min. The rates usual in St. Louis are either flat rates, some as low as $10 per elevator per month, or power rates, about 4 cents per HP. hr. Referring to Mr. Wells' paper, he expressed preference for an electric plant of three 100-KW. units, rather than the provision of units of different size (two 125-KW., one 100-KW., one 50-KW.), as outlined by Mr. Wells. The author, however, justified his choice on the score of reliability, which is of utmost importance in a New York city office building, perhaps more so than in western cities, on account of the nervous temperament of the people. Mr. R. L. Gifford (Chicago, Ill.) and Mr. G. W. Nistle (Chicago, Ill.) also defended the electric elevator, Mr. Gifford, however, conceding first place for heavy, constant service to the hydraulic elevator. Mr. Nistle gave a rule for estimating the required number of elevators, as follows: height of travel, divided by speed and divided by the desired interval between cars; the result must be multiplied by an arbitrary constant, which the speaker has found to be 3.3. The floor-area of the elevators depends on more general considerations; it should generally be at least 20 and not greater than 40 sq. ft. Mr. H. H. Suplee (New York, N. Y.) called attention to the general lack of ventilation in office buildings, and the need for providing artificial ventilation. He instanced the Drexel Bldg. in Philadelphia as a lone case of a fully ventilated office building. Mr. G. I. Rockwood (Worcester, Mass.) also spoke of ventilation, which, he said, has hitherto been dodged by owner and architect alike. The duct system is out of the question, of course, but ventilation by disc fans on each floor should be perfectly practicable. He mentioned the plunger elevator, not spoken of in the papers, as a promising type, attractive because its safety is so obvious. He considers this type destined to supersede both the electric and the cable hydraulic machine. Mr. Rockwood also came forward as the inventor and patentee of the Van Stone pipe joint, mentioned by Mr. Wells.

ELECTRIC AND HYDRAULIC CRANES.

Mr. Vincent L. Raven (Middlesbrough, England) contributed a paper entitled "Middlesbrough Dock Electric and Hydraulic Power Plant," which was essentially a claim for greater economy and convenience of electric dock machinery. The dock of the Northeastern Ry. at Middlesbrough, England, which handles imports and exports to and from Europe, was originally equipped with steam cranes. Fifteen years ago an extension to the docks was fitted with hydraulic cranes. Recently the steam cranes were replaced by electric. The electric appliances include: five 10-ton cranes, nineteen 3-ton cranes, and 26 capstans capable of pulling 1 ton at a speed of 200 ft. per min. The cranes are high gantries, straddling a railway track, and running parallel to this track. The jib has a radius of about 45 ft., and the total height of the upper jib pin is 60 ft. The hydraulic cranes are of similar dimensions. The electric equipment is described in detail in the paper. A competitive run of about five hours between electric and hydraulic cranes showed a saving of 25% in power cost and over 10% in time by the electric cranes. The author states that all concerned with the working of the cranes find the electric cranes to be a great advantage.

A communicated discussion from Mr. Ellington (London, England) questioned whether the comparison in the paper was fair to the hydraulic cranes. These latter were admittedly 15 years old, built at a time when little attention was given to economic use of power in docks, while the electric cranes were most modern. The subdivision of costs of the boiler plant afforded a chance for error in apportioning the proper share of cost to each kind of cranes, but the method of doing this is not explained in the paper. The author claimed that with a better "load factor" for the electric cranes, such as would ordinarily be obtained (as compared with that prevailing during the test), the advantage of the electric cranes would be still greater. This neglects the fact that hydraulic cranes, working with accumulators, always have a much higher load factor than the electric. Mr. John Barr (Kilmarnock, Scotland) also came to the defense of the hydraulic crane. He complained that the paper does not give the items composing the costs cited, nor does it give the first cost of the two plants. He criticised the slueing machinery of the hydraulic cranes as old-fashioned, and pointed out that while the electric cranes were equipped with expensive power traveling mechanism, the hydraulic cranes were traversed by hand, and this fact has been cited in their disfavor. He doubts whether the electric cranes always work as smoothly and unobtrusively as the hydraulic. Moreover, the hydraulic plant constantly works against the accumulators, at nearly full load, and requires a smaller reserve. He held that the

author had exhibited an undue leaning toward electric cranes.

Under the title "The Use of Superheated Steam and of Reheaters in Compound Engines of Large Size," Prof. L. S. Marks, of Cambridge, Mass., presented a number of tests on large high-speed vertical compound four-valve engines built by McIntosh, Seymour & Co. These engines were tested with and without jacketing and reheating, and the results analyzed. The author's general conclusions as to engines of this type are:

The jacketing of the high-pressure cylinder is of but little value when moderately superheated steam (100° F.) is used.

Reheating is probably a source of loss unless it superheats the receiver steam at least 30° F., and is not fully effective unless it superheats about 100° F. In the latter case it may be expected to effect a saving of 6 to 8% of the total heat used per I. H. P.

Jacketing the low-pressure cylinder is shown by the steam qualities during expansion in the low-pressure cylinder to be unnecessary and therefore undesirable when the reheating is effective.

The variation within the ordinary limits of the ratio of stroke to diameter in large size engines of the same power when using moderately superheated steam does not have any marked effect on the economy of the engine. The size of the engine is an important factor in determining its efficiency.

Mr. C. V. Kerr (New York) stated that recent load tests of the 5,000-KW. engines at the Waterside station, New York, had shown both jackets and reheaters to be practically useless. These engines, though designed for superheated steam, were being run on saturated steam. The tests showed the best results with superheating receivers. Mr. G. I. Rockwood (Worcester, Mass.) commented on the reported engine performance as poor, the same remark applying to the engines at the Waterside station, which are using 11.8 lbs. of steam instead of 9½ lbs., in part due to the large clearance (15%) caused by the valves being designed for superheated steam. The author did not note whether separators were used, or whether the reheaters had to evaporate the moisture in the receiver steam. Mr. Rockwood also noted that nothing was said of the increase in capacity due to reheating. Mr. Geo. H. Barrus (Boston, Mass.) criticized several features of the paper, among them the inclusion of unpublished tests other than the author's own and the use of a form of report other than the standard recommended by the society.

Mr. W. P. Flint (East Pittsburg, Pa.) presented a paper on "Commercial Gas Engine Testing and a Proposed Standard of Comparison." He argued for the need of a standard by which the economic performance of different gas engines may be compared, and suggested that such a standard may be found by referring the results to those of a "standard" 100-HP. engine having a mixture displacement, on suction stroke, of 345 cu. ft. of gas per minute. If the total gas consumption of any engine, at any load, be reduced to this standard by dividing by the ratio of its mixture displacement to the standard, the resulting artificial consumption may be plotted on a standard diagram. Similar engines of different sizes will then give curves which almost coincide.

In discussion Mr. R. Mathot (Brussels, Belgium) presented a number of test results obtained from European gas engines. Mr. E. J. Chambers (Wolverhampton, England) proclaimed himself an enthusiast for gas engines for works driving, and advocated putting in as large an engine as possible rather than several small ones. He favors the gas producer with gas engines as far ahead of the steam engine, and cited his experience as to greatly lowered cost of power over the steam engines replaced by the gas plant. Mr. D. S. Jacobus (Hoboken, N. J.) pointed out that the author departed from the standard recommended by the American Society of Mechanical Engineers, particularly in allowing for moisture in the gas. He criticized the author's arrangement for cooling the Prony brake internally by water with feeding and outlet pipes dripping into the water as being liable to cause error in the power readings.

A voluminous paper entitled "The Effects of Strain and of Annealing in Aluminum, Antimony, Bismuth, Cadmium, Copper, Lead, Silver, Tin and Zinc," by Mr. William Campbell (New York), which forms Appendix IV. to the sixth report of the Alloys Research Committee, was presented to the meeting at its last session. The paper is a cyclopaedic report on the structures found on the surface of small ingots and buttons of the metals mentioned in the title, when examined microscopically, both in normal condition and after strain and annealing. The paper is very fully illustrated with photomicrographs. We pass it without fuller notice.

Similarly comprehensive in its nature was a paper by Mr. W. J. Keep (Detroit, Mich,) on "Cast Iron, Strength, Composition, Specifications." This paper includes a great amount of information about the influence of various elements upon the strength of the iron, and many curves showing the variation of strength and silicon. In the proposed specifications given at the close of the paper together with a summary of the most common specifications current, the author attacks the American Foundrymen's Association's recommendation that transverse test bars be round, 1¼ ins. in diameter, cast on end. He prefers a square bar, cast flat in an open mold. Mr. Thos. D. West in a communicated discussion asserted that round bars give very uniform results, and that they should give no trouble in homogeneity if cast from the top. He claimed that any test bar, no matter what its form, requires an experienced molder, so that the argument of more difficult molding advanced against the round bar does not hold. On the other hand, square bars will be affected by poor corners, and will be troubled by moisture in the sand, etc. Mr. E. J. Chambers (Wolverhampton, England) stated that in England the standard for transverse test bars is 2 × 1 ins., tested on edge, 3 ft. between bearings. He did not favor close restrictions on chemical composition, because the proper mixing of irons is so important and is involved with other considerations than mere chemical composition. Mr. L. W. Crosta (Nottingham, England) pointed out that in English practice the test bars are often cast on bearings, so that their position, size and shape are at the option of the foundrymen. The inspector then specifies the size to which they shall be machined. Often the runner is used to make the test bar. Thus the form of the test bar is no troublesome question in England. Mr. Keep suggested that the practice of testing 2 × 1-in. bars on edge in England might be due to the desire of showing higher strength. Mr. J. H. Wicksteed (Leeds, England), however, thought that the testing on edge was a more severe test of the ductility of the metal. No general agreement as to size and shape of test bar was apparent from the discussion.

A paper of much interest was presented by Prof. J. T. Nicolson (Manchester, England) under the title "Experiments with a Lathe-Tool Dynamometer." The work reported is a measurement of the vertical, lateral and transverse pressures on a lathe-tool while taking various cuts at various speeds in steel and cast iron. For making the measurements a very effective dynamometer was constructed in which the pressures were transmitted to hydraulic cushions and read by means of Bourdon gages. The cutting speeds used varied from 1 ft. in 5 hours up to about 100 ft. per min. Experiments were made to determine the effect of shape of tool, cutting angle, rake angle, etc., on the tool pressures and the life of the tool. The results of this work, which is not yet completed, are presented in detail in the paper, where the dynamometer used is also described. Of the results we can mention only the observation that the cutting pressure does not vary greatly with the cutting speed, the pressure rather decreasing as the speed increases; that the cutting pressure is nearly 100 tons per sq. in. area of cut, for cast iron and soft steel; and that the cutting pressure increases about in proportion to the depth or area of cut, that is that the stress of cutting remains about constant with varying area of cut. The slow-speed experiments showed the variations of pressure as successive chips sheared off, and indicated the cause of the vibrations which require stronger machines for higher cutting speeds.

The paper called out a general appreciation of its value by Messrs. J. H. Wicksteed (Leeds, England), H. Emerson (New York), C. H. Benjamin (Cleveland, O.), J. McGeorge (Cleveland, O.) and Wm. Pilton (Hamilton, O.). Mr. Pilton referred to some experimental work along the same line which has been done at the Niles Tool Works, Hamilton, O., with a general result, for steel, corresponding fairly well with the pressures obtained by Prof. Nicolson. For cast iron the results varied too greatly to enable figures to be given. He pointed out that it was not absolutely necessary to have machine tools of new design in order to use high-speed tool steels, but that many old lathes can make good use of these steels if their countershafts are speeded up so as to give sufficient speed with back-gears in, when the belt will be sufficient for the pull.

Three papers on locomotive testing closed the meeting. Mr. E. A. Hitchcock (Columbus, O.) presented a paper on "Road Tests of Consolidation Freight Locomotives," Prof. F. M. Goss (Lafayette, Ind.) a paper on "Locomotive Testing Plants," and several English authors a paper entitled "Testing Locomotives in England," wherein the locomotive testing equipment and methods of various English railway lines are briefly described.

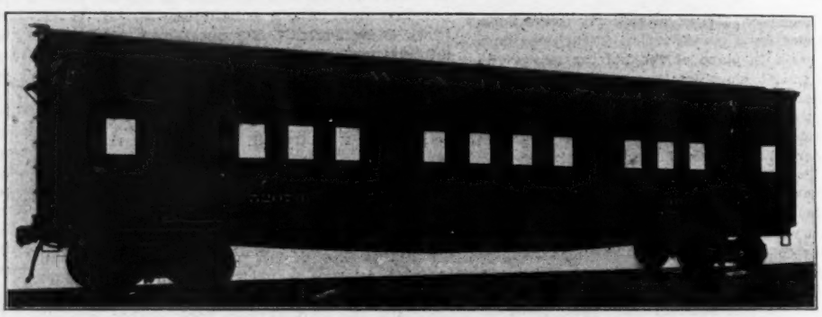


FIG. 1. SPECIAL SIDE-DOOR CAR FOR LOCAL TRAFFIC AT THE ST. LOUIS EXHIBITION; WABASH RY.
American Car & Foundry Co., St. Louis, Mo., Builders.

The tests described by Mr. Hitchcock were made on locomotives of the Hocking Valley Ry., and embrace full observations on the performance of engine, boiler and accessories on two engines during several runs over a 75-mile division from Columbus to Cary, O. Indicator diagrams, and "heat balances" in which the nature and amount of losses are indicated, are also given in the paper. The paper was briefly discussed by Messrs Wm. Forsythe and A. Bement (Chicago), but nothing of general interest was brought out.

The paper of Prof. Goss is a description, in some detail, of most of the locomotive testing plants yet built. These plants are: that of the Russian Southwestern Ry., built by Mr. A. Borodin, at Kieff, Russia, in 1881; the first plant of Purdue University, Lafayette, Ind., 1891; the second Purdue plant, 1897; the plant of Mr. R. Quayle at Kankanna, Wis., 1894; the plant of the Chicago & Northwestern Ry. at Chicago, 1895, also built by Mr. Quayle; the testing plant of Columbia University, New York, 1899; and the plant of the Pennsylvania R. R. Co. at St. Louis, Mo., 1904, which plant is to be used for extensive tests during the coming season. The plants described all involve the same general idea; mount-

ing the engine on a set of idle wheels to which load brakes are applied for measuring the power developed, and a traction dynamometer to measure the pull of the engine. The paper on English testing plants comprises mainly a note by Mr. G. J. Churchward of the Great Western Ry., describing a plant recently put in by that company at Swindon for the purpose of testing all finished locomotives, and a note by Mr. W. F. Pettigrew of the Furness Ry. on service testing on that railway. These two papers, being wholly descriptive, are not suited for abstracting in this place, but require to be read in the original.

The next annual meeting of the American Society of Mechanical Engineers will be held at New York city on Dec. 6 to 9, 1904.

SPECIAL CARS FOR LOCAL TRAFFIC AT THE ST. LOUIS EXHIBITION; WABASH RAILWAY.

A special train service between the Union Station and the exhibition grounds at St. Louis has been instituted by the Wabash Ry., as described in our issue of Jan. 28, and for this service 150 cars of special design have been built at the Detroit shops of the American Car & Foundry Co. These cars have steel underframes, and after the close of the Exhibition they will be converted into furniture cars. They are mounted on the Wabash Ry. standard type of freight car truck, with cast-steel truck bolsters. The boxes are of cast iron, with pressed steel lids, and have Harrison dust guards. The cars are equipped with Westinghouse brakes, Gould couplers and the builders' design of twin-spring draft rigging.

The special feature is the seating arrangement, which is shown in the drawing, Fig. 1. There are no end doors or platforms, but on each side are four sliding doors, those of each side being operated simultaneously from the outside by means of a lever, as shown. A central aisle extends the length of the car, and at each end is a seat the full width of the car. The seats are of wood. The seating capacity is for 92 passengers, but of course many more will be carried during the busy hours. For the convenience of standing passengers there are handrails hung from the carlines. The general dimensions of the cars are as follows:

Length inside	50 ft. 0 ins.
Width, inside	8 " 9 "
Height, sill to plate	8 " 7½"
Trucks, distance c. to c.	40 " 0 "
Truck wheelbase	5 " 3 "
Wheels	650 lbs.; diameter 2 ft. 9 ins.
Journals (M. C. B.)	5 × 9 "
Width of doors	21½ "
Capacity, seating	92 passengers
Capacity, freight	80,000 lbs.
Weight, empty	45,150 "

In this connection it is of interest to recall the special cars built by the Illinois Central R. R. for similar traffic at the time of the Columbian Exhibition at Chicago in 1893. These were designed to be converted into box cars, and had the ordinary construction of freight car underframe, roof and trucks. They were 35 ft. long and 8 ft. 6 ins. wide over the sills, with a height of 7 ft. 5 ins. from top of sill to top of plate. Transverse seats with low backs divided the car into eight compartments, each seating 12 persons. In each side were eight doorways 20 ins. wide, but there were no doors, but simply hinged bars or guard rails to prevent entrance or egress. The eight doorway bars or guard rails were operated simultaneously by a lever at the end of the car, this lever being operated by an attendant on the platform. These cars were described very fully in our issue of Nov. 17, 1892.

A view of one of the Wabash Ry. cars is shown in Fig. 2, but while the design is ingenious and seems likely to meet the requirements, it must be said that the appearance is very unsightly. It would seem that the railroad company might well have adopted a less prison-like severity and ugliness for cars to carry passengers to the Exhibition, more especially as it has spent a large sum of money for an ornate railway station at the Exhibition grounds.

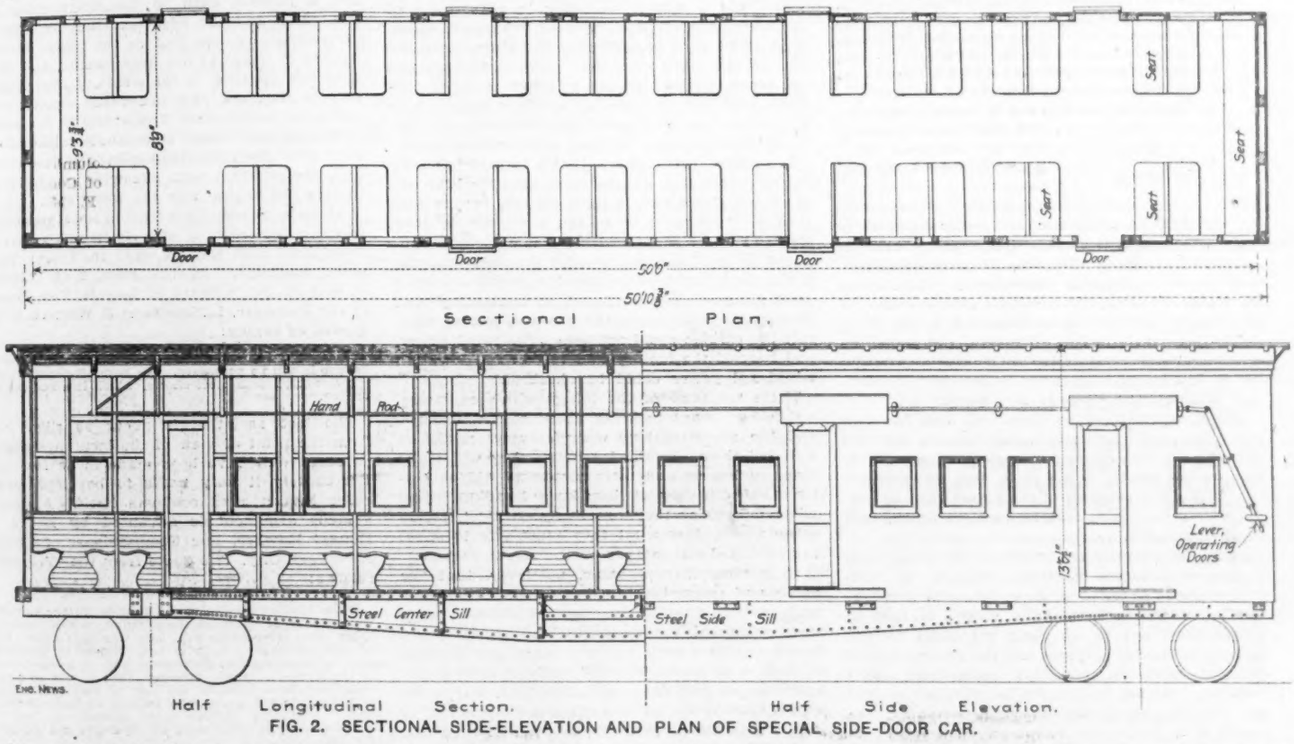


FIG. 2. SECTIONAL SIDE-ELEVATION AND PLAN OF SPECIAL SIDE-DOOR CAR.

THE GRAND TRUNK PACIFIC RY. bill has been passed by the Canadian House of Parliament by a vote of 105 to 59. This provides for the new trans-continental railway from Moncton, N. B., to Port Simpson, B. C., a total distance of about 3,120 miles. The eastern section, from the Atlantic coast to Winnipeg, will be owned by the Dominion Government, but built and leased by the Grand Trunk Pacific Ry. The railway company will build and own the western section, from Winnipeg to the Pacific coast. This great project was fully described in our issues of Oct. 22 and Nov. 5, 1903.

THE STEAMSHIP "MANCHURIA" has been completed for the Pacific Mail Steamship Co., at the yards of the New York Shipbuilding Co., at Camden, N. J. The "Manchuria" is a sister ship to the "Mongolia," which was delivered about two months ago, and she has the following main dimensions: Length, 616 ft.; breadth, 65 ft.; depth to shelter deck, 52 ft.; load draft, 33½ ft., and displacement 27,000 tons. The vessel is driven by twin screws operated by 10,000-HP. engines.

A NEW SPECIFICATION FOR ASPHALT, for use in laying street pavements, was adopted by the Board of Estimate and Apportionment of New York City on May 20, excluding asphalts affected by the action of water. The clause referring to this reads as follows:

The refined asphalt shall be obtained by refining crude natural asphalt until the product is homogeneous and free from water. Asphalt obtained from the distillation of asphaltic oils will not be accepted. It must not be affected by the action of water; must contain not less than ninety (90) per cent. of bitumen soluble in carbon-disulphide, and of the bitumen thus soluble in carbon-disulphide not less than sixty-eight (68) per cent. shall be soluble in boiling Pennsylvania petroleum naphtha (boiling point from 40 to 60 Centigrade); or, if it does not contain sixty-eight (68) per cent. thus soluble in the naphtha, but is satisfactory in other respects, the deficiency may be supplied by fluxing the refined asphalt with such a percentage of a viscous liquid asphalt, satisfactory to the Engineer, as will bring it up to the required standard.

ANOTHER SERIOUS HEAD COLLISION on an electric interurban railway is recorded. On June 2, near Norwalk, O., on the Lake Shore Electric Ry., a fast passenger car and a package freight car collided while both were running at high speed, killing six persons and seriously injuring a dozen others. The company operates an electric railway between Cleveland and Toledo, 118 miles, and ordinary cars make the trip in 6 hours, or at the rate of about 20 miles per hour, including all stops. In the parts of the line in the open country, however, the schedule calls for 30 miles an hour, including stops, a rate as high as that of most express trains on steam railways.

A FOUR-CYLINDER BALANCED COMPOUND LOCOMOTIVE, now being built by the Baldwin Locomotive Works for the Chicago, Burlington & Quincy Ry., is peculiar in that, while all the cylinders are in line at the smoke-box (as in the engines for the Atchison, Topeka & Santa Fe Ry., described in our issue of March 31), they are not all connected to the same axle. The outside low-pressure cylinders have very long piston rods, with connecting rods to the rear drivers, while the inside low-pressure cylinders are connected to the crank axle of the front drivers. The arrangement is thus a combination of the De Glehn and Von Borries' systems. The engine is of the Atlantic (or 4-4-2) type, with cylinders 15 × 26 and 25 × 26 ins., and driving wheels 6 ft. 6 ins. diameter.

A BOND ISSUE of $2,044,200 is to be made by the city of Chicago for permanent improvements. The special purposes on which the money will be expended are noted below, and the five new bridges will be at Northwestern Ave., 37th St., Archer Ave., Eggleston Ave. and North Ave.:

Extension of electric lighting system	$200,000
Seventeen new fire engine houses	298,200
New public baths, five wards	75,000
Retiring sewer bonds, approximately	150,000
New police station, Lake View	20,000
Five new bridges, plans for others	901,000
Miscellaneous construction, bridge repairs, etc.	400,000

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In requesting change of mailing address, state BOTH old and new address; notice of change should reach us by Tuesday to be effective for the issue of the current week. The number on the address label of each paper indicates when subscription expires, the last figure indicating the year and the one or two preceding figures the week of that year; for instance, the number 325 means that subscription is paid to the 32d week (that is the issue of Aug. 10) of the year 1905; the change of these figures is the only receipt, unless one is sent by special request.

ADVERTISING RATES will be furnished upon application. "Want" and "For Sale" notices (special rates), see pages 26-27. The pages for new "Want" "Proposal" and "For Sale" advertisements are held open until Wednesday noon.

"The field of application of steam turbines is very wide and it is certain that a great future is in store for them." We quote this concluding sentence from the paper in this issue by Prof. Rateau on steam turbines, since it well expresses one of the reasons why we have deemed it worth while to reprint nearly in full all four of the papers on steam turbines read at the international meeting of the English and American Societies of Mechanical Engineers at Chicago last week.

We print these papers, however, with full recognition of their limitations and defects; they are valuable because better and more complete literature on the subject is not to be had; and because it behooves the engineer of the present day to post himself on the steam turbine question by the best means available.

So far as quantity is concerned, there has been no lack of literature on steam turbines. The several concerns engaged in the commercial exploitation of steam turbines have waxed diligent in contributing papers on their machines to the pages of technical journals and the proceedings of technical societies, but they have been, quite naturally, careful to give out for publication only the roseate side of the story. Accordingly, the engineering profession has been thoroughly informed as to the advantages of the steam turbine. We all know how compact it is, what high results in steam economy it can show under test, how little this economy falls off under variable load, how it saves in the cost of dynamo construction, how little oil it requires, how the steam can be discharged into a surface condenser and used over and over again with resultant saving in feed water expense.

All these claims have been diligently spread before the public; but one may search long and find little concerning the other side of the story; and what the prospective user of steam turbines or the engineer who advises him wishes to know is not the strong points of the turbine, but the weak points. Before one takes the step of purchasing a machine which is such a radical innovation on past practices as the steam turbine, he wants to know what difficulties he is going to encounter. To read an article extolling the turbine as a marvel of perfection and preserving an entire silence as to its defects is apt to set a conservative engineer at work investigating to find what these defects may be.

Now, there is nothing like a little healthy competition to spread knowledge concerning the defects and weak points of any class of products, and the prospects are excellent at present for a season of sharp competition in the steam turbine business.

Thus it happens that in the four papers read at Chicago last week by the representatives of four different turbine makers, the several contributors managed to reveal some of the defects of their competitive machines, and incidentally of steam turbines in general.

In making our abstracts and condensations of these several papers, we have been careful to preserve those portions intact in which each author criticised his competitor's designs; and the whole symposium is calculated, we believe, to be of much practical usefulness to the engineer responsible for the selection or purchase of a steam turbine. It is true, of course, that very much more knowledge than is given in these papers would be desirable; but enough is given to put the engineer on the search for more.

Thus we learn that notwithstanding the published claims that the turbine buckets run for years without erosion, it appears that under some circumstances quite rapid erosion does occur. We learn that a minute variation in adjustment of the working parts, such as wear is likely to cause, may affect very considerably the steam economy of a turbine. We learn that centrifugal force sets up heavy stresses in the rotating parts of turbines, and that in case any accident causes it to run above its rated speed these stresses may become great enough to burst the rotating part.

It appears, furthermore, that a turbine is pretty closely dependent on the condenser for high efficiency and demands a high vacuum for the best results. A year or more ago a factory in New England was equipped with a steam turbine, supposed to be of ample power for the work, but the power was based on condensing practice with a good vacuum. The condenser as installed proved inadequate to maintain the vacuum, and as a result the turbine could not deliver its rated power, and part of the factory had to be shut down till additional power could be obtained.

These are some of the things which engineers, we believe, want to know about steam turbines, and the steam turbine manufacturers might as well tell them. In the long run, they will make more customers and their customers will be better satisfied if they let them know in advance just what difficulties they are likely to meet, or, in other words, just what they must pay to offset the admitted advantages of the steam turbine.

It is altogether probable, moreover, that the makers of steam turbines have themselves much to learn and that in the rapid evolution that is now going on, the steam turbine of ten years hence will be a very different machine from that of to-day. It is comparatively easy to build a machine which will effect a certain end; but it requires slow evolution through large experience to adapt that machine to all the conditions of use, to facilitate construction, erection, cleaning, lubrication, maintenance, renewal of parts, inspection, attendance, etc.

One other fact which deserves notice here is that the advantageous applications of the steam turbine, apart from dynamo driving, are yet to be demonstrated. There is much popular enthusiasm concerning its application to the propulsion of vessels, but, as Prof. Rateau points out, its use in this field, aside from vessels intended for phenomenally high speed, is of doubtful advantage. Propellers to run at the high rotative speed of a steam turbine are bound to be inefficient, and while the turbine itself is a perfectly balanced machine, the propeller is likely to set up worse vibrations in the hull than those caused by reciprocating engines.

Probably the most promising field for the use of steam turbines, aside from the electrical field, is the driving of centrifugal pumps. There is good reason to believe that the turbine-driven centrifugal pump may actually displace the reciprocating pump in many fields. It is such a small and inexpensive machine to build compared with the slow-moving steam pump, and the advantage is so great in dispensing with a multitude of valves and packings and stuffing boxes, that the manufacturer who will place a satisfactory unit of this sort on the market should find plenty of patronage. Of course, here again erosion is likely to be a matter requiring attention, but the castings for the pump once made could probably be renewed at a small expense compared with the cost of keeping up the valves and packing and all the other multitudinous parts requiring attention on the ordinary direct-acting steam pump.

The fire which destroyed the Jersey City piers of the Delaware, Lackawanna & Western R. R. on May 29, naturally calls to mind the greater disaster of four years ago when the North German Lloyd piers and steamships were burned with a horrifying loss of life. Fortunately this latest harbor front fire has no such bloody record as the former to impress it on the public mind, but its lesson is quite as evident to those who search for it. This lesson is that the existing harbor front structures of American cities are, for the most part, veritable tinder-boxes which are a menace both to the neighboring shore structures and the adjacent shipping. There is no question of this fact in the minds of underwriters or heads of fire departments, and there is even less question in the minds of thoughtful observers that the only safeguard against continued great water-front fires exists in fire-resisting piers and pier sheds. It is idle to talk of fighting such fires from the land side, and few cities, if any, are provided with adequate means for combatting the flames from the water side.

In view of these facts some of the statements respecting fire-resisting pier construction that have come from high sources since the recent fire, deserve comment. In the New York "Tribune" of May 31, Mr. Edward E. Loomis, Vice-President of the Delaware, Lackawanna & Western R. R., is quoted as saying:

> With regard to rebuilding with fireproof piers, I don't believe it will be necessary. We have all our sheds on the piers covered with steel sheets, which is a sufficient protection.

The last assertion is about as silly, judged from the point of view of the insurance engineer, as could well have been made in as few words. Fortunately it only needs to be emphasized in order that it shall condemn itself. A more ingenious argument is advanced by Mr. J. McDougal Hawkes, late Commissioner of Docks of New York City. We quote from the "Tribune" as follows:

> When I was Commissioner I went to Europe and studied the system of ferro-concrete piling, which consists of using piles of concrete with long iron rods inside, instead of wooden piles. It is a new system of construction used in Southampton, Rotterdam, and, to a certain extent, in Antwerp. I found, however, that it was so heavy it could not be applied to the port of New York, because piles here do not go to solid bottom, as there is so much mud. I studied various other systems of fireproofing while abroad, but they were all expensive and not suitable for this port.
>
> There are no really fireproof piers here, except the stone piers at Pier A and Pier 1. Stone piers, however, are exceedingly expensive, and they are not elastic. In some cases the cost would be prohibitive. If there is a hard bottom a stone pier can be built; but if there is soft mud, and you have to go down 120 ft., the expense would be enormous. An attempt has been made to cover the planking of wooden piers of New York with concrete and asphalt, but it has never been definitely approved. The wooden pier gives more or less, but the concrete does not give.

Mr. Hawkes, it will be observed, simply repeats the threadbare statement that timber pile pier supports only are practicable at New York because of the mud bottom. Granting that this is true, must we also grant that a more fire-resisting construction than is now practiced is not possible? Because the concrete and stone harbor basins of Europe are not practicable at New York, must we, therefore, continue to use scantling and corrugated iron for our water-front structures? At least one large dock owner has found it possible to do better. The North German Lloyd piers at Hoboken have a concrete and steel beam platform carried on timber piles and surmounted by fire-resisting freight-sheds. To prevent the fire from getting underneath the piers, they are sheathed at the sides and ends to a point well below the water level. It is needless to say that

European quay construction, which consists of solid earth filling between masonry quay walls, ranks on an entirely different standard as regards durability and safety from fire than does a construction of the kind described, but that does not alter the fact that the construction described is considerably superior to prevailing practice, and would, if generally adopted, go far toward preventing the occurrence of harbor front fires of large dimensions.

We are receiving numerous letters asking how positions may be obtained on the Panama Canal work. In answer to these inquiries it may be said that the entire matter of the appointments on the work rest with the Isthmian Canal Commission, and applications for positions should be addressed to the Commission, which has its headquarters in the Evening Star Building, Washington, D. C. Applicants should state what class of position they desire and give a full statement of their qualifications and experience, as they would in making an application for any position.

Civil service rules will be followed in making appointments, the exact details being still undecided. It should be said, however, that for some time to come, possibly for a year or more, there will not be many more positions on either the clerical or the engineering staff of the Commission to be filled, as considerable time will be consumed in the preparations for the actual prosecution of construction work.

THE QUALITY AND CONSISTENCY OF CONCRETE FOR CONCRETE-STEEL WORK.

One of the greatest dangers to the future development of reinforced concrete lies in the fact that it can be so easily employed by unskilled and unprincipled persons. It will be urged, of course, that the same claim holds true of any other structural material, that the incompetent and the dishonest designer and builder is as free to employ his questionable practices with steel and wood as he is to employ them with concrete. This is only partly true; there is an evident difference between concrete construction and construction with rigid materials. In concrete-steel work the manufacture of the material, the fabrication of the structural member, and the erection of this member in place in the structure are substantially simultaneous operations. The scamp designer in steel may cut down his sections and he may botch his erection, but he cannot to any serious extent deteriorate the quality of his steel. With concrete-steel work the builder can cheapen his material as easily as he can scamp the design and workmanship. It is necessary, therefore, that engineers should have a very clear conception of what concrete for concrete-steel work should be.

Save in exceptional cases, Portland cement alone is employed for reinforced concrete. The aggregates used with the cement are sand and broken stone or gravel. The only exceptions to this practice are the use of cinders and crushed slag with Portland cement for certain forms of fireproof floor construction, and the use in Europe of a quick-setting natural cement for manufacturing cast pipe reinforced by a metal skeleton These are examples of special practice and only stone and gravel mixtures are considered here. For these only the best qualities of materials are allowable in concrete-steel work, and their proportioning and admixture must be so controlled as to produce a concrete that is sound, homogeneous and strong to an exceptional degree. The reason for this is easy to see.

When used as a substitute for stone masonry in walls, piers and foundations, concrete may suffer local disintegration or have local weaknesses without serious danger to the integrity of the structure as a whole. The case is different when it is used as a beam or column in place of steel or timber. Here local weaknesses due to unsoundness or want of homogeneity are elements of positive danger in the structure. To the experienced engineer these facts need no emphasis, but nowadays the widespread use of concrete places its manufacture in the hands of many who are not engineers, and the fact that concrete will endure a large amount of mishandling and still serve fairly well its purpose for ordinary masonry work is likely to give the impression that it can be mishandled safely when used for reinforced beams and arches. This is not the case.

Excellence of materials and manufacture is quite as important an element in producing a serviceable and durable concrete-steel structure as is excellence in design. In fact, a poor design is more safely allowable for such a structure than are poor materials and workmanship. In receiving this caution against poor materials and workmanship, it should not be misinterpreted to mean that impracticable requirements of manufacture are necessary for good results. This is far from the actual fact. Only the ordinary standards of excellence are demanded. In fact, in insisting upon the need of a high quality mixture for reinforced concrete work, care should be taken not to carry the demand to extremes. To demand for a floor filling a concrete equal in quality to that in the reinforced plate, or for a bridge abutment a mixture as rich as that in the arch ring is usually unnecessary for the stability of the structure, and is poor engineering. This is a structural principle which has been well worked out in the practice of European engineers of concrete-steel work. As an example, in building the Melan arch at Laibach, Austria, described in Engineering News of July 16, 1903, the heavy abutments were begun with a 1-14 concrete and the mixture was gradually increased in richness to a 1-3-5 concrete at the top.

The matter of the proper composition of concrete for concrete-steel naturally follows from what has just been said. Practice furnishes a wide gamut of mixtures from which to choose. In Monier construction a mortar composed of one part cement and three parts sand is used for thin slabs for floors, partitions, tanks, conduits, etc., and a mortar composed of one part cement to 4 or 4½ parts of sand is used for arch bridges and similar heavy work. Some others of the European concrete-steel constructions use a mixture of cement and sand only, but the greater number employ a true concrete of cement, sand and broken stone. In the United States concrete is employed almost exclusively. The proportions adopted are 1-2-3, 1-1¼-4, 1-2-4 and 1-3-5. The most common mixtures are 1-2-4 and 1-3-5, but there is no uniformity of practice and apparently no settled opinion as to the best mixture for general use or for special classes of construction.

There is a tendency at present to use leaner mixtures for concrete-steel work than have been used in the past. This is based largely on the fact that lean mixtures are less likely to develop shrinkage cracks and fissures, and are stronger provided the mortar is sufficient in quantity to fill thoroughly the voids. The danger from using leaner mixtures lies in the fact that a more careful grading of the aggregates is necessary and that the mixing must be unusually thorough, and these are the things which are the most difficult to secure in ordinary work. European engineers have made a success of lean mixtures for the same reason that they succeed with dry mixtures; they put a large amount of work into the manufacture and deposition. A rich mixture like a wet mixture assures safety against insufficient and inefficient labor in mixing and ramming the concrete. European builders in reinforced concrete are as a rule advocates of lean mixtures and dry mixtures, but they recognize their permissibility only in case the mixing, deposition and compacting are performed with exceeding care.

In the United States wet mixtures are now almost universally employed for concrete-steel construction. This choice is dictated largely by practical considerations. With the amount of care which it is ordinarily practicable to secure, a more dense and homogeneous concrete is obtained with a wet than with a dry mixture. It is also practically necessary in order to ensure the thorough embedding of the reinforcement, that the concrete be wet enough to flow readily under moderate ramming into all the interstices of the metal skeleton. This quality is particularly desirable when the reinforcing elements are of small size and are closely spaced. The adhesive strength of concrete to embedded steel is largely affected by the continuity of the bond between the steel and concrete, and continuity of bond or perfect contact are most easily obtained with wet mixtures. Perfect contact is also necessary, as has been shown by recent tests, for the preservation of the embedded steel from corrosion. Another decided advantage of wet concrete is that a more impermeable mixture is secured.

These practical advantages of wet mixtures for reinforced concrete are held by experienced engineers generally to be sufficient to overbalance such objections to them as actually or theoretically exist. In this connection it must be remembered that the fear once anticipated, that a serious loss of strength would result from the use of an excess of water has been shown to be largely unwarranted. The most complete and trustworthy experiments to determine the relative strengths of wet and dry mixtures are those made by Mr. Geo. W. Rafter, M. Am. Soc. C. E., in 1896 for the State Engineer's office of New York. Mr. Rafter made 12-in. cubes of dry, plastic and wet mixtures. In the dry blocks the mortar was only a little more moist than damp earth; in the plastic blocks the mortar was of the ordinary consistency used by masons; in the wet blocks the water was so far in excess that the concrete quaked like liver under moderate ramming. The resulting average compressive strengths of the three sets of blocks were as follows:

Dry mixture	156 blocks,	2,470 lbs.	per sq. in.
Plastic mixture	144 "	2,294 "	" "
Wet mixture	148 "	2,180 "	" "

The blocks tested were all from 18 to 24 months old. These tests and in fact laboratory tests in general indicate a somewhat greater strength for well-rammed dry mixtures. Evidence is not lacking, however, that wet mixtures develop greater strength ultimately. However this may be, the difference is not material. From a practical standpoint, the fact remains that unless there be a liberal use of water the mass cannot be properly consolidated by any reasonable amount of ramming. The use of a wet mixture economizes labor and produces a sounder and better product. In the case of concrete-steel there are the added advantages that a wet mixture insures a better bond between the concrete and the steel, and that it gives the steel better protection against corrosion.

LETTERS TO THE EDITOR.

Is There a Means of Neutralizing the Gases Following a Blast in a Tunnel?

Sir: In mining short tunnels by hand, without air, trouble is experienced from powder and gelatine fumes, compelling loss of time.

I beg to inquire as to the possibility of correcting this by spraying a liquid or releasing a gas that would neutralize or absorb the fumes and purify the air. Perhaps you or your readers could give information on this point. If there is nothing yet on hand for the purpose, it might pay a good chemist to look into it, as even when air is used I have known such trouble to occur.

Yours truly, A. B. C.

Sago, W. Va., May 26, 1904.

Corrosion of a Steel Stack.

Sir: Referring to the communication of "Pocahontas" in your issue of May 26 relative to the corrosion of the interior of his high stack, it occurs to the writer that there is less destruction near the base, by reason of the protecting coat of soot which is always thicker at that end.

There is probably no preventive which will last for more than a few years. The writer's own experience suggests a graphite paint especially prepared for meeting the conditions. The stack should be thoroughly cleaned with a wire brush, or better, with a sand blast. Two coats of the paint should then be applied, the surface being slightly heated. Ample time, of course, should be given for the drying of each coat. With these precautions a "fair degree of protection" should be possible.

Yours very truly, Capt. John Smith.

A Pamphlet Defending the Metric System: Correction.

Sir: In Engineering News of May 19 (Engineering Literature Supplement, p. 51) I notice that the Bureau of Standards is credited with publishing a pamphlet entitled, "Answers to Objections to the International Metric System." The pamphlet is not in any respect a publication of the Bureau of Standards. Upon inquiry I find that it is a reprint by the American Metrological Society of Bulletin No. 23, issued by the American Chamber of Commerce in Paris. A few copies of the pamphlet in question were sent to the Bureau of Standards, but I am unable to find that more than three or four of these were ever sent

out by the Bureau, and then only upon special request, as no copies of the original bulletin were at hand.

Respectfully, S. W. Stratton, Director.

Department of Commerce and Labor, Bureau of Standards, Washington, May 25, 1904.

The Sewage Disposal of London.

Sir: In your issue of May 12, a copy of which you were kind enough to send me, I notice on page 442 in your note on the London Sewage Disposal System you say: "it has been practically decided to change from chemical precipitation to septic tanks and contact beds."

As such a change in the case of London would be a complete revolution of the system adopted only 15 years ago, I beg to inform you that no such decision has been come to.

Some very valuable experiments as regards septic tanks and contact beds have been made and some further beds will no doubt be constructed during the next five years to deal with a small portion of London sewage. Such extensions must, however, for many years be considered of an experimental character. I do not think anyone suggests the wholesale change which your note suggests.

Yours faithfully, Maurice Fitzmaurice,

Chief Engineer London County Council.

County Hall, Spring Gardens, London, May 24, 1904.

Supporting Power of Piles Driven by a Steam Hammer After Standing.

Sir: In answer to Mr. Goodrich's request for pile driving data, I submit the following, which was done under my supervision:

Nov. 20, 1902, at 5 P. M., a Warrington steam hammer weighing 5,000 lbs., and having a fall of 3 ft., struck 11 blows on a slim 60-ft. Norway pine pile in soft mud, causing it to sink 42 ins. The last two blows went 3½ ins. each.

Nov. 22, at 7 A. M., (38 hours later), 11 blows of the same hammer caused the pile to sink only 6½ ins. The first blow went ¾-in. and the last ½-in.

Tests were made on several piles that had been driven a month. In hard pan the bearing had increased 30 to 50%, while in soft mud the increase was nearly 300%. In the first case the length of pile was 40 ft. and in the latter, 70 to 75 ft. Very truly yours,

Robert Follansbee, Assistant Engineer.

Reclamation Service, U. S. Geological Survey.

Malta, Mont., May 31, 1904.

What is the Pressure of Green Concrete Against the Forms.

Sir: I would be glad to hear through the columns of the News of any observations and investigations that your readers may have made on the lateral pressure of green concrete against forms. I have not come across any data on the subject and it seems as if the universal use of concrete should make any such information of general interest.

Take for example a retaining wall. If "wet" concrete is used, each layer exerts a pressure from being a semi-fluid mass and even slight ramming increases this pressure, probably to a point equal to that of a comparatively frictionless liquid of the same specific gravity as the concrete. In using "dry" concrete the ramming induces a wedging action that gives a pressure greater than any that could be figured from the weight of the mass acting statically.

Opportunities for roughly measuring this pressure arise in the field, where it is found the forms lack stiffness. The deflection of the boards between supports would give an approximate value for this.

Yours truly, Geo. M. Bacon.

Salt Lake City, May 31, 1904.

A Template for Platting Cross-Sections.

Sir: The accompanying sketch, Fig. 1, illustrates a form of template which I have used for many years for platting cross-sections for record. Using a piece of transparent celluloid, the line B C, width of roadway required, is drawn to the scale required to be used, the lines A B and C D are then drawn to the required formation slopes, 1½ to 1 for embankment, and 1 to 1 for earth excavation; then the center line a H is drawn, and the scale to be used is constructed on it. When the form is cut out on the lines A B C D it will be found very useful for the purpose required.

In practice two scales of heights will be found very convenient, making one of them the double of the other—say 5 ft. to the inch and 10 ft. to the inch—so that extra large sections may be platted on the reduced scale, using the same template or forms.

Quite recently W. and L. E. Gurley have undertaken to supply these forms and to avoid making different forms for different widths of roadway a form that may be used for any width of roadway has been devised—as shown in Fig. 2. Lines O A and O D are inclined to the horizontal lines A D in the ratio 1½ to 1; line O E is perpendicular to A D and the two scales are constructed to plat one of them 5 ft. to the inch, the other 10 ft. to the inch, making the zero of the scales at O. In practice, then, it would be necessary to add to the height of fill, on the center line of the section, the height O a, Fig. 2, to give the height on the scale to set the form for drawing to lines A B and C D. This height O a is a constant for each different

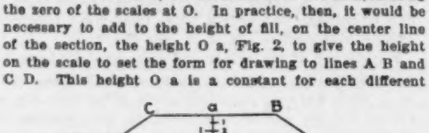


Fig. 1.

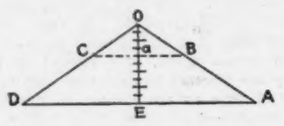


Fig. 2.

width of roadway and equals ⅛ the width of roadway for embankment slope of 1½ to 1, and ½ the width of roadway for slopes of 1 to 1. The line B C may be drawn showing the width of roadway in use or even the form may be cut away on line B C, adapting it to draw the three lines A B, B C and C D at one setting of the form.

Yours truly,

J. M. Rudiger.

150 Nassau St., New York City, May 12, 1904.

The Desirability of Experience Tests of Cement for Engineering Works.

Sir: In an editorial in Engineering News of May 5, you raise the question: "Is the modern test of hydraulic cements a reliable criterion of the suitability of any particular cement for engineering construction?" This question is evidently answered in the negative by the large, and as you say, increasing number of engineers who exclude from their work all cements which have not been successfully used for a number of years, thus requiring that a cement shall not only pass the usual laboratory tests, but also the "long time" test of actual use. You quote an advocate of the experience test as saying that laboratory tests are unreliable because the experimenter can produce any desired result. But, as it seems to me, this is but a small part of the difficulty. Is it not possible (and I have reason to believe that it is) that a manufacturer, either from ignorance or design, could produce a cement which would pass all the standard laboratory tests, and yet fail completely in the far more important and conclusive test of actual use in engineering construction?

I by no means wish to imply that a cement should be accepted on the strength of its reputation alone. Both tests are needed; the test of experience to show that the cement manufacturer certainly did produce good cement at one time, and the laboratory test to show that he probably still does so. For a laboratory test is but a more or less successful attempt to find out in a short time, what may be learned with more certainty, but much more slowly, from practical experience. It seems to me perfectly logical to condemn any cement that fails to pass the laboratory tests, and also to refuse to accept any brand of cement without an established reputation. I can not agree with your remark that "There can be little fairness, however we contrive, in insisting that no cement shall be used which does not pass tests unless we grant that a cement which does pass tests may be accepted." All good cements will pass the tests, but the converse is not true. All cements which will pass the tests are not good.

Yours truly, Winslow H. Herschel.

Zürich, Switzerland, May 16, 1904.

The Stresses in Riveted Joints.

Sir: There has arisen a question in regard to the stress on the different rivets in a connection where they are in a straight line, this line being the line of action of the stress-producing force. So far as I am aware, this kind of a riveted connection has never been thoroughly analyzed and the result put into such a form that it can be used. If such analysis has been made and published, I would thank some one to tell me where I will find it. I claim that if there are more than two rivets in a row, along the line of action of the force, the two end rivets will receive the greatest stress and the stress on the intermediate rivets will decrease as the number of rivets from either end increases. If there are a good many rivets in such a connection it is possible that some of the rivets near the center will be neutral and will receive no load at all.

The rate of decrease of stress on each rivet will depend upon the relative hardness of the two members riveted together and the rivets, the relative size of the rivets and the thicknesses and widths of the two members and the distance between the rivets.

I claim that the end rivets have to give way enough for the metal between the first and second rivets to become in tension or compression, as the case may be, before any load at all comes on the second rivet. In the same manner the second rivet has to give before stress is put on the third rivet, and so on until we come to the rivet on which there is no stress at all until the end rivet has completely given way.

I once had quite an argument with a friend [illegible] to convince him that I was right in my assumption. I placed a flat strip of rubber on a soft pine board and [illegible] stuck five common pins through the rubber into the board, spacing the pins in a straight line about ¾ [illegible] part. I then slipped the rubber up from the board [illegible] heads of the pins and then pulled one end of the [illegible].

The accompanying sketch shows the result which I think proves that my theory is correct. Of course the rubber greatly exaggerates the thing, but I think that we can safely assume that what is true in this respect of pins and rubber is also true of steel.

If any one will try this and use enough pins he will find that the spring in the pins will continue to decrease until a pin that does not spring at all has been reached. He will also find if his rubber is strong enough that the end pin will give way first, then the next, and so on until all the pins have been bent over.

While the illustration shows the pins giving way only at one end, we must not get the idea that in an actual riveted connection this would be true; it is only seen in the illustration because one of the members is wood and is practically inelastic, while the other member is very elastic.

I will be pleased to know some one else's views on this subject.

Draftsman.

Homestead, Pa., May 23, 1904.

(Undoubtedly, if rivets enough are placed in line, the rear rivets will sustain practically no load. It is to be remembered, however, that the rivet acts in direct shear, and not like the long elastic pins shown in our correspondent's sketch. Thus the stretch will occur in the plates joined, and it is in this way that stress is carried back to the rivets in the rear, so that if no more rivets are used than are sufficient to develop the ultimate strength of the plate, they may with little error be considered as all acting together.—Ed.)

Practice in Water Softening Plants.

Sir: The great amount of space in your May 26 and June 2 numbers devoted to papers on that very important subject "Water Softening" cannot fail to provoke wholesome discussion among those interested in the subject. The first paper, presented by Mr. James O. Handy, to the Engineer's Society of Western Pennsylvania, evidences his wide study of the art; so that his criticisms of the various systems investigated are entitled to special consideration by all who have in contemplation the installation of water softening plants, but who have not looked into the subject so deeply. With much that Mr. Handy says the writer can cordially agree. He feels it all the more incumbent upon him, therefore, to point out certain statements which appear to him to have been made without the care and accuracy displayed in the greater part of the paper.

The use of flat-bottom tanks for settling purposes—in large softening units for industrial plants, at present, and in municipal plants when the American public realizes the benefit from softened water—instead of cone-bottom tanks, is, emphatically, good practice, both because of the extra space occupied by the cone bottom and because of its relatively large cost. In fact unless an angle of 45° is approximated, the beneficial effect for the attainment of which the cone is installed does not follow, as the space tributary to a discharge opening is that bounded by such a cone. Moreover, it is extremely doubtful whether the accumulated sludge will slide over a surface less inclined.

Mr. Handy's criticism of the method of disposal of sludge from the flat-bottom settling tank in the machine on the Pennsylvania Lines West of Pittsburg, installed by the Industrial Water Co., seems to have been made without complete knowledge of the construction of the sludge pipe system there in use. While it is evident that he has had experience with sludge removal from flat-bottom tanks, as witness the cut of the municipal water softening plant of Winnipeg, installed by him, his judgment condemning this practice is hasty, as will appear from the following: In the Winnipeg plant each of the two 30-ft. settling tanks is provided with a set of eight 6-in. sludge openings, each set controlled by a single 8-in. valve. Each of these sludge openings has an area of 28.27 sq. ins., making an aggregate area of 226.16 sq. ins., for each set, while the valve governing the common outlet has an area of but 50.26 sq. ins. It is obvious that any two of

the sludge openings, such as those nearest the valve, would be capable of conducting to it all the water it could pass. It follows, that the efficiency of the other sludge openings is bound to be low and it will only be a matter of time before those farthest removed from the valve will give evidence of being inoperative.

In the machine on the Pennsylvania Lines West of Pittsburg, above referred to, the aggregate area of all the sludge openings in the bottom of the settling tank is *slightly less* than the area of the blow-off valve and piping, so that when the valve is operated, each opening becomes effective to the full value of its area, no matter whether located adjacent to, or on a part of the bottom remote from, the blow-off valve. In substantiation of this statement, the writer may say that he knows personally of such settling tanks which have been operated continuously for more than two years, and without the necessity of disposing of the sludge by means other than by the blow-off pipe. Of course, the bottom is never absolutely clear of sludge but the device employed is sufficiently effective to prevent the accumulation of sludge beyond a fixed maximum, small in amount.

The absence of settling cones in the Industrial machine "for ensuring an even upward rise in the settling tank" is noted as an objection to this design. If Mr. Handy has made experiments with cones and without, as did the designers of this machine, he no doubt would have discovered how much—or rather how little—benefit is derived therefrom. It is patent, moreover, that Mr. Handy has not seen fit to employ cones in his Winnipeg installation.

From the published description, it appears to the writer that one of the principal difficulties at the Winnipeg plant—but which is not designated as one of the "troubles" and which seems to have been accepted as a matter of course—is the use of lime tanks of insufficient size. If the lime tanks had been made of adequate dimensions, the operation could have been simplified and the results made more uniform, as will be seen from the following:

1. The necessity of pumping cream of lime in approximate proportion to the demand would be obviated, so that the frequent empirical adjustment of the cream of lime pump would be unnecessary. Lime could be slaked in a receptacle from which the cream of lime could flow by gravity to the lime tank. Of course during the short period when the new charge was being introduced into one of the lime tanks, all of the lime water could be taken from the other lime tank.

2. Cream of lime need be prepared but twice instead of fourteen times during a 24 hours' run, when running at the rate of 1,510,000 Imperial gallons per day.

3. The small excess of cream of lime "always present in suspension" in the lime water would be practically eliminated, so that this excess, varying as it is bound to do, need not be "taken into account," thus rendering unnecessary the hourly tests of the lime water.

4. Variation of the rate of pumping of the water to be treated would have been far less of an inconvenience than at present, as the well-known method of apportioning the proper amount of water to a lime tank containing on its lower part a supply of cream of lime, is bound to provide automatically for any variations in pumping, up to the capacity of the plant.

The point brought out by Mr. Handy, relative to the quality of lime which can most economically be used, is one which should be borne in mind by all who have to purchase lime for the purpose of softening water. Good building lime burned in some parts of Ohio and Indiana, for instance, very frequently contains but 50% of calcium oxide, which is the active agent.

Turning to the extract of the paper read by Mr. Stromeyer before the Institution of Mechanical Engineers of Great Britain, it appears that he has gone into the subject fairly exhaustively from a theoretical standpoint. It seems a pity though that he has made himself responsible for the following statement: "On cooling down a boiler, and letting it stand for some time, the water will dissolve parts of the crystals (calcium sulphate) until there are about 170 grains to the gallon. This dissolving action loosens the scale, which can easily be removed as long as it is wet." If he has since tried in practice this method of removing calcium sulphate scale, he will doubtless wish to revise his statement concerning this matter.

Yours truly, L. M. Booth,
Manager Industrial Water Co.

126 Liberty St., New York City, June, 3, 1904.

Hydrated Lime.

Sir: In your issue of Oct. 8, 1903, there appeared an article on hydrated lime, in reply to my article published in your issue of Aug. 27, 1903. Inasmuch as I have been conducting a test to show the comparative merits of high calcium and magnesium limes, I have delayed reply to secure additional proof of my statements.

In the May issue of "Rock Products" there appears such a severe criticism of my article above referred to that I send you the results of the test as far as it has been conducted. The article in "Rock Products" under the subject "Lime Experiments," among other things criticised the method of making the cement tests. In answer to this, the mere fact that the principal cement tests shown in my article were made by Mr. S. B. Newberry is sufficient in itself, and no other proof as to their reliability is needed.

The statement was also made that very few bolting reels are being used in connection with the manufacture of hydrated lime at this time, the air separator having superceded the bolting reel. I am prepared to verify the statement which I now make that not over 15% of hydrated lime now being turned out is separated by the air method, the bolting reel being employed in the manufacture of the other 85%. Such firms as the Rockland-Rockport Lime Co., Kelley Island Lime & Transport Co., the Toledo White Lime Co., the Western Lime Co., and J. B. Speed & Co. all use bolting reels.

Another statement made in the same article was to the effect that quick lime when properly burned is not liable to pop after being slacked and put on the wall. This statement is so clearly in error from a practical standpoint that it seems strange that it should be made in an article of this kind. Every mechanic knows that pitting and popping is one of the most serious difficulties met with in all finishing lime whether quick lime or prepared lime.

It is difficult to interpret the meaning of the article in reference to the presence of MgO on account of grammatical errors, but if it is intended to hold that indications point to the presence in any quantity of $MgOH_2O$ in freshly hydrated lime made from Dolomitic limestone, I would say that we hold letters from Booth, Garrett & Blair and from G. A. Kirchmaier, whose ability is too well known to require comment, showing that analysis of such hydrate indicates the presence of water in practically the exact amount required to hydrate the CaO present—although there is no way of verifying the fact that there is not a partial hydration of both CaO and MgO. It is fair to assume, however, that if the material does not subsequently swell, that the CaO is completely hydrated. In all probability the difference between the results in my test of cement with hydrate and those made by Mr. Warner is due to the fact that the hydrate of lime used in my test contained free lime, otherwise the tensile strength should not decrease after 14 days. This simply emphasizes the statement already made time and again in articles on this subject, that the greatest of care must be used in preparing hydrate and unless a reliable brand is selected it would be much better to let hydrated lime entirely alone. There are several reliable brands on the market made by good firms who exercise care in the preparation of same, and these should be used in preference to the cheaper grades which are now flooding the market. Small particles of core or unslacked lime, too small to be detected by the eye, are bound to exist where any of the sprinkling or other crude methods are employed, and these particles by gradual swelling and slacking exercise strength sufficient to weaken the best Portland cement. As stated above, this was undoubtedly the cause of the decrease in strength shown in my briquettes after 14 days.

In discussing the relative sand carrying and spreading qualities of the high calcium and dolomitic limes, the writer of the article above referred to shows that he has had no practical experience with these two limes and that he is not familiar with the practical results obtained from the use of the high calcium lime. The criticism made by Mr. Charles Warner, however, in your issue of Oct. 8, is perfectly correct and his position is well taken, although Mr. Warner did not correctly interpret my statement that the magnesia lime would not carry as much sand as high calcium or fat lime. The ordinary bricklayer, contractor and even the owner pays no attention, as a rule, to the quality of his mortar. He will have elaborate tests made on his cement and will select the best brand, but when it comes to mortar anything that will lay between the brick is good enough. If the owner or even the contractor had any idea of the difference in tensile strength between the mortar made from magnesia lime and that made from calcium lime, he would not consider the use of the latter for an instant in any building designed to stand for over one year. The mason will mix his lime and water to the consistency that he thinks is right and if it looks a little thick he will put in more water and vice versa. He will then throw in sand until he thinks it looks right and the mortar is ready to use.

As a matter of fact, the high calcium lime will take more water and is more bulky when slacked than the magnesia lime and the mason, by his crude method of mixing, will invariably put in more sand with the calcium lime than with the magnesia. It is for this reason, in this section, that the masons and contractors prefer the calcium lime, for actual tests will show that in laying a certain number of brick less lime is required with the calcium than with the magnesia lime. If they would look into the matter a little further they would easily discover that the mortar from calcium lime has about one-half the tensile strength of that made from magnesia lime and if it has been prepared with the proper amount of sand to give equal tensile strength, the magnesia lime would have laid about 60% more brick than the calcium lime.

This can also be stated in the following manner: If each mortar were prepared with the proper percentage of sand so that the same amount of lime would lay an equal amount of brick, the tensile strength of the magnesia lime mortar would be largely in excess of the tensile strength of the calcium lime mortar. With this explanation, it is evident that Mr. Warner is correct, but at the same time I maintain that my statement was right for the reason that in practical work no one cares whether the mortar is good or bad, and as the mason finds it cheaper and quicker to make the bad, and neither the contractor nor the owner objects, the calcium lime will be used every time for the above reason.

The magnesium oxide present in all dolomite limes after slacking apparently has strong cementing qualities and may account for the comparative weakness shown in the high calcium limes after they have stood a short time. In actual practice it is shown in the Middle West that the mortar made from calcium lime shrinks away from the brick, and after standing for a few years the wall can be taken down and the brick cleaned almost by hand, while the reverse is true when the magnesium lime is used, the mortar and the brick being so strongly bound that frequently in cleaning the brick itself will break before the mortar can be separated from it. In the Middle West, however, the practice in favor of the cheaper lime is so great that the writer knows of several cases where dolomite lime has been specified by the owner, and calcium lime substituted by the brick contractor, because it was cheaper, as above explained.

If the lime industry ever reaches the state that the cement industry is in to-day, I believe that practically no calcium lime will be used in mortar, and as a result you will see none of the crumbling walls with mortar washed away by the rains, which is such a common sight at the present time.

I give below the results of the test which I am now carrying on, as far as it has been conducted:

Tensile Strength in Pounds per Square Inch of Magnesia Lime Two Parts Sand to One Part Slacked Lime by Weight.

4 weeks.	8 weeks.	3 months.	4 months.	6 months.
		42	58	90
		45	45	75
		32	43	77
		34	55	90
		40	57	83
8 lbs.	17 lbs.	30	48	..
		37 1-6 aver.	51 aver.	83 aver.

Tensile Strength in Pounds per Square Inch of Calcium Lime Two Parts Sand to One Part Slacked Lime by Weight.

4 weeks.	8 weeks.	3 months.	4 months.	6 months.
32	31	40	46	57
27	36	38	51	50
30	39	36	24	45
22	41	43	40	56
32	36	..	47	57
41	..	..	26	40
30 2-3 aver.	36 3-5 aver.	39 1-4 aver.	39 aver.	50 5-6 aver.

It will be seen that the magnesia lime rapidly gains in strength and at the end of a year should be fully double that of the calcium. Probably in time the magnesia mortar would show three times that of the calcium mortar, and as soon as the test is completed, showing the twelve months and the two year results, I will be glad to have them published.

Yours very truly,
S. Y. Brigham.

Toledo, O., May 20, 1904.

Notes and Queries.

The paper describing a concrete-steel highway bridge at Plainwell, Mich., published in our issue of May 12, had previously appeared in nearly the same form in "The Michigan Engineer," the annual publication of the Michigan Engineering Society. This had escaped the attention of the editors of this journal or due credit would have been given in publishing the paper.

Errata.—"The Building Construction of the St. Louis Exhibition."—In this article in our issue of May 19, the following corrections of typographical errors should be made: Page 480, top line of middle column, "150 ft." should be "105 ft."; p. 480, in the compression formula, the factor "2" should be "1"; p. 481, fifth line of first column. "destructive" should be "detrusive"; p. 484, 19th line from bottom of third column. "30 ft." should be "80 ft."

Mr. P. T. Markham, Chief Building Engineer, also calls our attention to the fact that the first word of the last paragraph on p. 484 should be "our" instead of "these." The word used would imply that the figures given in this paragraph result from the weights quoted from Mr. Picket in the preceding paragraph, but as a matter of fact they result from the weights of the exhibition buildings. The weights of the truss framing of these buildings (Table II on p. 482) are much higher than those given by Mr. Picket. This is thought to be due to the fact that the latter's figures do not include the additional strength and weight due to the truss being used as a member of a knee-bracing system to transmit a horizontal wind force to the ground.

THE EXTENSION OF THE PARK SYSTEM OF New York is recommended in a recent report of the Park Committee of the Municipal Art Society. Among the areas recommended for parks are the crowded promontory at the northern end of Manhattan Island, Blackwell's Island, in the East River, and a system of park areas on Staten Island.

THE COST OF CAST-IRON PIPE.*

By John W. Alvord,† M. Am. Soc. C. E.

No subject gives the water-works man more anxiety from season to season than to properly place his orders for cast-iron pipe, so as to take advantage of the market so far as possible. And it very often happens that expensive extension become necessary when the pipe market is at its top notch, and, on the other hand, it is difficult to finance improvements when pipe is low. The importance of determining the amount and character of fluctuations in the pipe market is one that has been fully realized, but so far as the writer is aware, there is nothing on record which will give a clear idea of the amount and character of these fluctuations.

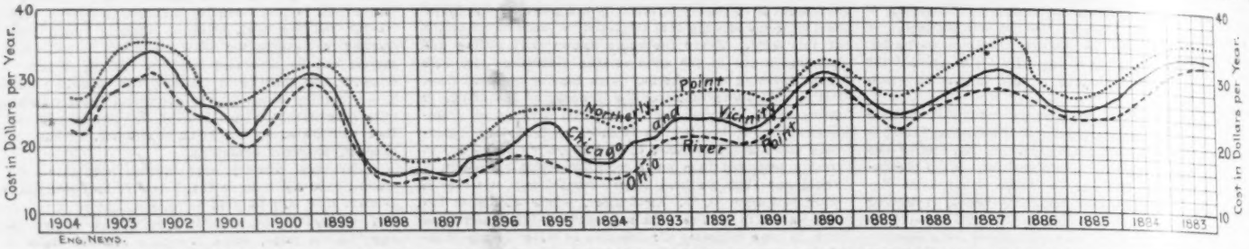


DIAGRAM SHOWING COST OF CAST-IRON PIPE, 1882 TO 1904, IN THE STATES OF ILLINOIS, MICHIGAN, WISCONSIN, OHIO, INDIANA, MISSOURI, TENNESSEE, KENTUCKY, MINNESOTA, NEBRASKA, MASSACHUSETTS, NEW YORK, NEW JERSEY, KANSAS, DISTRICT OF COLUMBIA, IOWA.
Compiled from Engineering News by John W. Alvord, C. E.

Having had some occasion to obtain information as to the average cost of pipe during the last ten years, the accompanying diagram has been prepared showing the actual contracts which have been made since 1883 for cast-iron pipe in the States of the Central West centering about Chicago.

No effort has been made to reduce these prices to a common freight rate from the factory, but they have been plotted just as they have been taken from the Engineering News and other sources, the lower dotted lines showing the average prices at Ohio River points and the upper line at the more remote points in the Northwest.

This diagram cannot fail to be of interest to all those who are watching current prices, and who may be able to reason from the past as to what the probabilities are for future contracts.

REMOVING FLOATING BOG FROM A PARK LAKE.

A novel plan for clearing a lake in a park at Newark, N. J., has recently been adopted, and is described as follows in the Newark "News:"

Preparations are about completed for deepening and clearing the lake in Weequahic Park to the extent of removing 720,000 cu. ft. of decayed vegetable matter and earth. The lake is about a mile long and covers ninety-three acres. The surface to the extent of some thirty acres is coated with floating bog, formed principally of cat-tails and other plant growth which thrives in marsh land. All of this is to be taken out.

At the time the problem of clearing the lake was first propounded, the Park Commission authorized William S. Manning, the superintendent of the county parks, to spend $10,000 if necessary on the work, and he set about the task. Olmsted Bros., landscape architects, were consulted, and in looking over the stretch of water with Mr. Manning they found the bed covered in places with bog. It was noticed, however, that around the springs, which feed the lake, and which are in the deeper places, the water was usually free from matter of this kind. This led to the suggestion that the water be raised 6 ft. or more, the idea being that the bog would float to the surface. Fear was expressed that the weight of water would blanket the springs and force them to seek an outlet at a point distant from the lake, but the method was finally tried.

The water was shut in until there was a depth of from six to twenty feet, with an average depth of eight feet. The springs were not blanketed, and the bog came to the surface until the lake became dotted with floating islands, some of them half an acre in area, and that part of the plan was pronounced successful. Mr. Manning then advised the commission to purchase and set up an ice elevating machine on a scow, with the aid of which the bog could be raised up out of the water and dumped on the land.

A scow was built and launched on the lake and an ice machine was purchased in the northern part of the state. The machine consists of an endless chain running up a runway out of the water. At intervals of four feet there is a crosspiece cleated to the chain and the pieces of bog were loaded on the crosspiece and carried up the runway and dropped on the land against which the scow was moored.

First of all, however, the pieces of bog are floated into a canal, flanked with heavy timber platforms extending out into the water, in which the men stand to work. Next the pieces, which average about 18 ins. in thickness are cut into chunks about 4 ft. square, either by means of long ice saws or large knives.

DIFFERENT APPLICATIONS OF STEAM TURBINES.*

By Prof. A. Rateau.†

One of the most interesting developments in mechanical engineering during the years 1902 and 1903 was the greatly extended use of steam turbines. This development is the result of efforts which have been made by various people to increase the efficiency of turbines to such a point that they may compete commercially with reciprocating engines. The author has been occupied for more than fifteen years in the study of rotary engines, and he has already published several papers upon the subject. He believes that in presenting to the Institution of Mechanical Engineers an account of the practical result of his labors upon steam turbines he will contribute usefully to the study of this important question.

Although the principles which distinguish the different kinds of turbines are well known, it may be useful to recall briefly their distinctive characters in order that his own type of turbine may be more easily distinguished. In common with all other steam engines, turbines transform into mechanical work the energy given out by steam during its expansion from the initial pressure of admission to the pressure at the exhaust. But whilst reciprocating engines effect this transformation of energy by means of variation in pressure of the steam, turbines can effect this transformation both by means of the pressure and by means of the velocity of the steam while expanding. The employment of the velocity only in each moving wheel characterizes the action or impulsion turbines, among which may be cited the De Laval and Curtis turbines, as well as that designed by the author; whilst the simultaneous employment of the velocity and partial use of the pressure characterize the reaction turbine, of which the best known type is that of Parsons.

Whatever may be the method in which the steam acts in the turbine the chief problem consists in the employment, with good conditions of efficiency, of the very great velocities attained by the steam in expanding. When the expansion takes place in one stage, as in turbines with a single wheel, then the velocity of flow reaches, as is well known in a condensing engine, a value which is usually above 3,000 ft. per second. But in order to obtain the maximum efficiency, the moving part of the machine should have a relative velocity which is approximately the half of that of the steam. As it is practically impossible to construct turbine wheels suitable for running with a peripheral velocity above 1,200 ft. per second, the efficiency of turbines with a single wheel is necessarily low, this being due chiefly to the necessity for the employment of diverging inlet nozzles, which give rise to great losses of energy by friction and eddying. On the other hand, angular velocities which [illegible] peripheral speeds prevent the direct [illegible] and render necessary reduction gears [illegible] construction, which, however, cannot [illegible] excessive wear, and are exposed to a [illegible]

A consideration of these circumstances induced inventors to divide the expansion of the [illegible] sive stages, and thus to produce turbines with multiple wheels, which are nothing but a series [illegible] mounted upon the same shaft and driven successively by the same current of steam. This design of multiple turbines is by no means novel. It will be sufficient to mention the name of Tournaire, a French mining engineer, whose theoretical description to the Academy of Science in 1853 of a re-action turbine with multiple [illegible] is surprising when the description is compared with the Parsons turbine brought into use 30 years later.

Every simple turbine may be designed either as an impulse turbine or as a re-action turbine. In the former kind the fall of pressure under which the simple turbine works takes place solely in the distributor, whilst in the latter type the fall of pressure takes place, not only in the distributor, but also in the moving wheel, so that in the latter type there is a higher pressure in the guide-vanes than at the exit. Fig. 1 represents the guide-vanes and the moving vanes of an impulse turbine, in which it is supposed that the fall of pressure is small enough at the vanes to render unnecessary the use of diverging nozzles as in the De Laval turbine. In the illustration the triangles of velocities are given at the entrance O A B, and at the exit O B C of the moving wheel. Similarly in Fig. 2 are shown the guide-vanes and the moving vanes of a reaction turbine, and the triangles of velocities at the entrance O A B and at the exit O B C of the moving wheel are shown in the figure. It is obvious from these illustrations that, by the mere inspection of the moving vanes, it is possible to distinguish between an action turbine and a reaction turbine. In the former type the vanes appear in transverse section in the form of an arc of a circle with entrance and outlet angles practically the same, whilst in the reaction turbine the cross-section of the vanes is in the form of a parabolic arc, the entrance angle being more or less approximately 90°, whilst the outlet angle is generally between 20° and 30°. Generally the vanes are increased in thickness in the middle, so that the steam spaces between them have approximately a constant transverse section for impulse turbines or decreasing section for reaction turbines. If, however, they are made of plate they may have a constant thickness as in

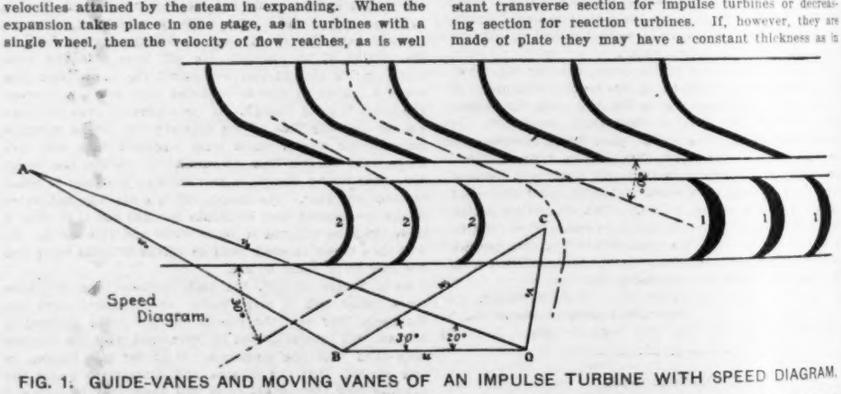


FIG. 1. GUIDE-VANES AND MOVING VANES OF AN IMPULSE TURBINE WITH SPEED DIAGRAM.

2, Fig. 1. In reaction turbines it is important that the increase in thickness should be suitably calculated otherwise there will be an important loss of efficiency. It is otherwise with the impulse turbine in which the efficiency is very little affected whether the vanes have a constant or variable thickness. In a given turbine with multiple wheels the different simple turbines may be all designed in the same way or some may be designed in one way and some in another way to produce a hybrid system.

DRUM TURBINES AND MULTICELLULAR TURBINES.—From another point of view, drum turbines may be distinguished from multicellular turbines. In the former type of which the Parsons turbine is the best known example, the moving vanes are fixed upon the periphery of

*A paper read at the annual meeting of the American Water-Works Association.
†Consulting Engineer, 127 Hartford Building, Chicago, Ill.

*Extract from a paper presented at the Chicago meeting of the American Society of Mechanical Engineers.
†Paris, France.

a cylindrical drum; in the latter they are fixed to the periphery of wheels more or less flat and separated from each other by diaphragms which divide the interior of the turbine into cells. The turbine of the author belongs to the latter type.

Fig. 3 is a diagram of a drum turbine, and Fig. 4 a diagram of a multicellular turbine. These two types have different properties, so far as losses of steam are concerned. In the multicellular action-turbine leakage of steam can only take place through the play c, Fig. 4, which exists between the shaft and the ring of the fixed diaphragm which surrounds this shaft. In the reaction drum turbine, on the contrary, leakage may take place: 1st, around the moving wheels in a, Fig. 3 (by reason of the reaction); and, 2d, in b through the play between the guide-vanes and the moving drum. The first leakage can be suppressed, if desired, by making the wheels work by impulsion instead of by reaction, but then the second leakage between the fixed vanes and the moving wheels

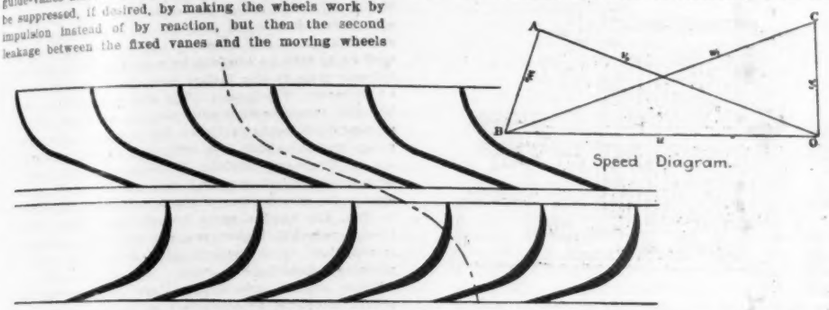


FIG. 2. GUIDE-VANES AND MOVING VANES OF A REACTION TURBINE WITH SPEED DIAGRAM.

attains its maximum. It is because of this leakage at the periphery of the drum that turbines of the Parsons type require the most accurate workmanship. It is easy to understand that a play of some tenths of a millimeter is sufficient, at least upon the high pressure side, to produce a cross-sectional area of the leakage passages equal to that of the admission passages between the distributing vanes; if by especially exact workmanship the cross-section of the leakage passages is made very small, is it not to be feared that after some years of use the wear of the parts, either by friction of the moving parts against the fixed parts or by the action of the steam, will increase the cross-section of the leakage passages and so cause a notable decrease in the efficiency of the machine?

In multicellular turbines the leakage, being confined to the periphery of the shaft, it reduced in proportion to the radii of the shaft and the drum; and, moreover, friction being less to be feared at a place where the relative velocities are smaller, the play may be reduced to the absolute minimum. In practice we do not trouble about giving this play any precise value. We build the machine with practically no play round the shaft, and when started the machine itself makes play sufficient to turn without touching the internal rings of the diaphragms.

FRICTION OF THE MOVING PARTS ON THE STEAM.—It would appear probable that multicellular turbines produce relatively large losses by friction of the moving parts upon the steam owing to the large surface of the moving wheels. This is, however, not the case. From tests which we have made to determine the law of friction, and also from the results of experiments made upon complete machines, we have found that frictional losses represent only from 2 to 4% of the normal power developed by the machine. These figures apply to turbines with an output exceeding 500 HP. These figures are comparable with those obtained in drum turbines in which the friction of the moving vanes themselves must be added to that of the cylindrical surface of the drum.

TURBINES WITH GROUPS OF WHEELS.—Another type of turbine which may really be considered as belonging to the impulse class is being built upon a large scale, and is known under the name of Curtis. In this type instead of using upon a single moving wheel the velocity of discharge of the steam leaving the distributor, it is used upon several wheels arranged in series in order to diminish the velocity gradually. The principle upon which the Curtis turbine is designed has been described in 1900 by Mr. Mortier in a discussion which took place after a paper had been read by the author upon steam turbines in general and upon the Parsons turbine in particular.*

The type which we have described as having a group of wheels possesses the notable advantage of allowing a great reduction in the speed of rotation for wheels of the same diameter and of the same number. It would therefore be preferred to all others if its had not, in our opinion, the grave defect of preventing a sufficiently high efficiency being attained. It is easy to see that, owing to the great velocity of flow of the steam in the first wheels, the losses of energy by friction and eddying are very great, reaching such a value that the second wheel develops less power than the first, and the third wheel less power than the fourth, when more than two are used, and they act more like brakes than prime movers. The Curtis turbine, as originally constructed at the Fisk Station in Chicago, had groups of four wheels, but the process of evolution reduced these to groups of three and then to groups of two wheels. Even with such a reduction in the number of wheels in a group the efficiency, according to our calculation, is still at least 20% lower than that obtainable with the multicellular turbine which has only one wheel per cell. The author therefore ventures to think that the Curtis type of turbine will disappear, as in the process of evolution it will become the multicellular type pure and simple.

DESCRIPTION OF THE RATEAU TURBINE.—Since 1894 the firm of Sautter-Harlé of Paris, with the assistance of the author, has been experimenting upon the construction of steam turbines. The first turbine constructed had only a single moving wheel, like the De Laval turbines, and this wheel was formed with vanes in the form of a double arc similar to the buckets of a Pelton wheel, and these vanes were milled out of a solid block of steel. This type has since been copied in the Riedler-Stumpf type, built by the Allgemeine Elektricitäts Gesellschaft, but which was rapidly abandoned as it did not offer any chance of obtaining the maximum efficiency. The most recent Rateau turbine is of the action type, that is to say, expansion of the steam is fully carried out in the distributor for each group consisting of a distributor and one moving wheel. The steam therefore acts by its velocity and not by its pressure. These turbines are moreover multicellular, that is to say, they consist of a certain number of elements, each element comprising one distributor and one moving wheel. A very interesting characteristic of the type of action turbines is the possibility which it allows of leaving very considerable play between the fixed parts and the moving parts, and this greatly facilitates construction and obviates the chances of dangerous friction if the bearings should become worn or the shaft somewhat bent. Besides this the wheels revolve in a chamber where the pressure is uniform. There is for that reason an absence of longitudinal thrust upon the moving parts and no necessity for the use of dash-pots for the purpose of overcoming the effect of this thrust, although such dash-pots are necessary in reaction or drum turbines. Finally, in the action type partial injection of steam is possible, that is to say, the steam may be directed upon a limited portion of the circumference. The moving wheels are formed of disks of sheet steel more or less thin, and upon the periphery of these disks are riveted vanes of cylindrical form. A steel band riveted to the periphery maintains the correct spacing of these vanes and insures great rigidity to the construction. Wheels so constructed are extremely light, and remain in equilibrium at a velocity far higher than that to which they are subject in the turbine. These moving wheels turn between circular diaphragms provided with distributing vanes which enter circumferentially into grooves formed in the interior of the turbine case. Between two adjoining diaphragms is therefore produced a cell or very flat chamber in which the moving wheel revolves. The shaft passes through the diaphragms in collars of anti-friction metal with very slight friction. In the first diaphragm which the steam passes through the distributing vanes are placed only upon a part of the circumference. Partial injection of the steam is therefore obtained, and thus the velocity of the steam is better utilized. Moreover, to produce the same effect the useful part of each distributor is set with an angular advance on the preceding section; this angle of advance is calculated according to the speed of rotation, so that the steam leaving one moving wheel enters into the following distributor and never encounters a solid wall which would produce a shock and therefore a loss of kinetic energy. For the last wheels it is necessary to employ total injection, that is to say, the distributing vanes must be set upon the whole circumference of the diaphragm, and moreover, owing to the expansion of the steam, the radius must be increased. The bearings of these turbines are external, and by means of a special system of spring packing they are kept perfectly tight. No oil is carried by the exhaust steam to the condenser, and this has an important advantage as the water of condensation can be used for feeding steam boilers direct without any necessity for the use of an oil-separator. The speed of rotation is controlled by a centrifugal governor with a Denis compensator, which acts upon an obturator which controls the pressure of steam entering the turbine.

MIXED TURBINES.—In the case of installations where exhaust steam must be used, a subject which we shall consider in detail at a later stage, it is often desirable to supply the turbines temporarily with steam at high pressure when the primary machine is stopped or is furnishing less steam, and the work done by the turbine must remain the same. In order to obtain economical working it is preferable not to expand this steam in order to lower it to the pressure for which the low-pressure turbine is built. Therefore, the author has designed a turbine which may be described as of the mixed type, and this can be supplied either simultaneously or separately by steam at high pressure and by steam at low pressure without any lowering of the efficiency of the mechanism. In order to attain this result the turbine is constructed in two parts, one designed for high-pressure steam and the other for low-pressure steam. The steam at high pressure having done work in the first portion will pass to the second portion, which may be fed either by steam coming from the accumulator or by the exhaust from the first portion. The admission of high-pressure steam into the first portion is automatically obtained by means of a special regulator which allows steam from the boilers to pass to the first portion as soon as the pressure in the accumulator falls below a given value. This arrangement, which has been adopted in all the new applications of the system to the use of exhaust steam, works very economically, and is particularly suitable to cases in which the primary machine works irregularly, and where therefore the demand for live steam is frequent and somewhat prolonged. In small machines the two portions are usually joined together.

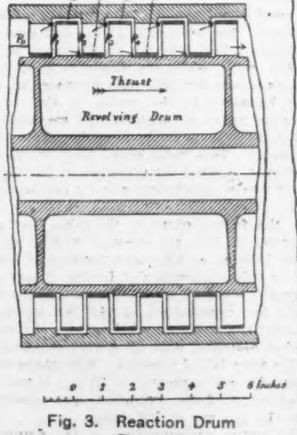


Fig. 3. Reaction Drum (Rateau).

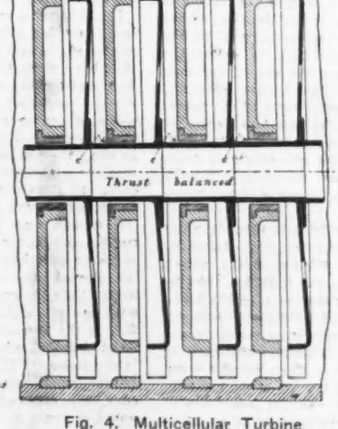


Fig. 4. Multicellular Turbine (Parsons).

EFFICIENCY OF TURBINES.—It is essential that the word efficiency should be clearly defined in order to avoid any misconception as to the figures which are given below. The author uses the expression "Theoretical consumption of the perfect machine" to denote the maximum work which the steam is capable of supplying when starting from the saturated or superheated condition in which this steam is delivered to the engine and expanding adiabatically with no loss of admission pressure P to exhaust pressure p. By comparing the actual consumption of steam as measured during the tests of the machine with this theoretical consumption of the perfect machine for identical conditions of pressure and similar states of the steam the net efficiency of the machine is obtained. After special study of the question, the author has been able to draw a curve of theoretical consumption and to derive from it the following empirical formula

*See Comptes Rendus de la Société de l'Industrie Minerale à St. Etienne. Meeting of April 12, 1900.

for use when the steam is saturated and dry at admission:

$$K = 0.85 + \frac{6.95 - 0.92 \log P}{\log P - \log p}$$

This formula gives the consumption K in kilograms per horse-power-hour of 75 kilogrammeters as a function of the absolute pressures P and p expressed in kilograms per square centimeter. In British measures this formula becomes:

$$K = 2.13 + \frac{16.20 - 2.05 \log P}{\log P - \log p}$$

K in lbs. per horse-power-hour, P and p in lbs. per sq. in.

If the steam is superheated, then of course the extra calorific energy corresponding to the superheat must be taken into account;* but for the exact estimation of this extra energy we have not as yet adequate precise knowledge of the specific heat of the vapor of water. At present we have merely the figure obtained by Regnault after very cursory experiments (0.48), a figure which is merely a rough approximation.

The author has begun some experiments from which he believes he will be able to prove that the true specific heat of steam is not constant, as has been usually supposed up to the present. It varies inversely as the amount of superheat, and is probably approximately unity for very small values of superheat, and approaches 0.40 for large amounts of superheat.

CALCULATION OF THE EFFICIENCY OF TURBINES.—The efficiency of a turbine may be calculated a priori when a preliminary study has been made of the practical coefficients which must be introduced into the theoretical formula. We calculate this efficiency with quite a remarkable degree of accuracy by dividing the losses of the machine under two headings: first, the internal losses which are produced by friction and eddying of the steam in the fixed and moving vanes; second, the external losses which correspond to the leakages of steam in the play between the fixed and moving parts, and to the friction of the wheels upon the steam and to the friction of the bearings. The first kind of losses gives rise to the internal efficiency, which may therefore be called the "hydraulic efficiency" by extending the use of the term employed for hydraulic turbines. This internal efficiency depends upon the more or less perfect form of the vanes, and also to the relation between the peripheral speed of the moving vanes and the speed of flow of the steam. It is possible to draw a curve showing the efficiency as a function of the peripheral velocity, and therefore it is easy to at once assign the degree of efficiency which a given turbine will realize.

Once having fixed the internal efficiency, then, in order to obtain the net efficiency, we must deduct the losses by leakage as well as the losses by friction of the wheels upon the steam, and also those in the bearings. Let us take, for example, a multicellular turbine of 1,500 brake HP. upon the shaft with a speed of 1,500 revolutions per minute. By means of practical coefficients found by experience we can calculate that the internal efficiency of such a machine may easily rise to 69%; on the other hand, the losses by leakage and by friction in the bearings absorb 1.5% of the normal power, and the losses due to friction of the wheels upon the steam amount to 2.5%, making a total for the external losses of 4%. The net efficiency upon the shaft at the speed stated will then be 0.69 multiplied by 0.76 = 0.66. From this value of efficiency it is easy to calculate the consumption of steam per horse-power-hour which would be required by this turbine under conditions of pressure and of superheat of the steam already determined. All calculations for designs of turbines that we have made by this means have always proved correct within 1 to 2 % of actual practice. Such accurate calculations are not possible in the case of reciprocating engines owing to the action of the cylinder walls, which makes calculations uncertain and often inaccurate, while in the turbine the continuity of flow of the steam allows practical calculations of a high degree of accuracy to be based upon theory, once having determined the fundamental coefficients which are employed in the formula. For a more detailed consideration of the use of these coefficients the author refers to the work which he published in 1903 in the "Revue de Mecanique," entitled "Theorie elementaire des Turbines à Vapeur."

THE RESULTS OF ACTUAL PRACTICE.—The author began the construction of his first multicellular turbines in the year 1898 in collaboration with the firm of Messrs. Sautter-Harlé, of Paris, and there are now already at work or in process of manufacture turbines developing more than 25,000 HP. in units varying from 10 to 2,000 HP. irrespective of the designs now in preparation. Some of these turbines are used for driving dynamos, others for pumps, for fans, and for the propulsion of vessels. The author has appended a brief abstract of the conditions and economical results of the most interesting of these installations.

TURBO-DYNAMOS FOR DIRECT CURRENT.—The company of the mines of Peñarroya in Spain installed in their central electric lighting station a little more than a year ago three groups of turbo-dynamos developing 500 electric HP. with direct current at 240 volts. Each of these three generating sets comprises two turbines for high and low pressure, and two dynamos for direct current, the latter directly driven from the turbines upon the same shaft and upon the same bedplate, and the two dynamos supply a three-wire network with a potential of 480 volts between the outer wires. The speed of rotation is about 2,200 revolutions per minute, and the floor space occupied by the turbine with its two portions is only 12 ft. by 5 ft. 6 ins., with a height of 5 ft., inclusive of a bed-plate 1 ft. high. The condensation of the steam is carried out by means of ejector-condensers of a type designed by the author.

Fig. 5 shows a longitudinal section of the turbine, which has 24 moving wheels. The work tests of the first group were made in September, 1902, with the greatest care, and they have given the results which are shown in Table I. The condensation was made for these tests by means of a surface condenser belonging to the works, so that, the water of condensation might be collected and measured. It will be seen that the vacuum at the condenser declined as the power increased. This result arises from the fact that the condenser was designed for machines of 250 HP. only, and therefore was of insufficient size for the larger volumes of steam.

It follows from the figures given in the table that a turbine developing 644 E. HP. and working without appreciable superheat between an admission-pressure of 156 lbs. absolute and an exhaust-pressure of 1.8 lbs. (notably higher than the results given by good condensers in practice) has given the low consumption of 14.9 lbs. per E. HP. at the terminals; the combined efficiency for the set being then 59% when compared with the energy contained in the steam for the same fall of pressure. With steam at 180 lbs. superheated 50° and a vacuum of 29 ins. of mercury, the consumption at 2,400 revolutions per minute would decrease to 11.5 lbs. per E. HP. hour.

Fig. 6 gives the curves corresponding to the figures taken at a speed of 2,400 revolutions per minute. The abscissæ denote the power of the machine in electric horse-power at the terminals of the dynamos. The ordinates vary with the curves. For curve A the ordinates denote the absolute pressure of the steam on reaching the turbine in pounds per square inch. For curve B they show the absolute back pressure at the exhaust in pounds per square inch. For curve C they show the total consumption of steam in pounds per hour, and for curve D they show the consumption per electrical horse-power in pounds per hour, and lastly for curve E they show the combined efficiency. These graphic curves show clearly a remarkable characteristic of turbines, which is the very low relative consumption of steam at small loads. It will be seen that in order to drive the turbine at its normal speed with no load, but with the dynamo excited, the total consumption of steam is only ... of that at full load. With reciprocating engines the result would be very different. Under similar conditions the consumption of steam at no load with the dynamo excited usually reaches from 20 to 25% of the consumption of steam at full load. It therefore follows that turbine sets are more advantageous than reciprocating engine sets when running at light loads, even supposing ... be admitted that there is equality at heavy loads.

Another valuable property of steam turbines is that they may be considerably overloaded without difficulty. Thus, in the case of the machines at Peñarroya, which were designed for 500 HP., they have been able to develop 650 E. HP., and the output could have been raised even still higher had it not been for the overheating of the commutators of the dynamos. In our machines we are enabled to take an overload by supplying steam to a distributor more or less distant from the inlet in the series of successive distributors. The stop valves which regulate this supplementary admission can be moved by hand or controlled mechanically by the governor. The second group was submitted to a competent committee (consisting of Professors Stodola, Wyssling and Farny of the Zürich Polytechnicum), and this commission found the figures for consumption of steam a little higher (from 2 to 4%), the ampère meter brought from Zürich having given somewhat higher readings than the instruments standardized by the central laboratory of the Ecole supérieure d'Electricité in Paris.

These sets of turbo-dynamos for direct current have proved somewhat unsatisfactory in practice, owing to the sparking of the brushes occasioned by the vibration of the armatures. The commutators of direct-current dynamos are, as is well known, the delicate parts of these machines, particularly when they have to run at such a great angular velocity as is necessary if direct coupled to steam turbines. In order to obtain sparkless running special arrangements must be made for absorbing the vibration, but it is very difficult to maintain in good equilibrium such heterogeneous bodies as the armatures of dynamos, consisting of bars of copper which become slightly displaced under the action of centrifugal force owing to the compression of insulating material. Special arrangements for static equilibrium, and also for dynamic equilibrium, have been designed, but the construction of the armatures is still always somewhat delicate, and it is only after several improvements that it has been possible to make them work well. At Peñarroya the vibrations were caused principally by want of level between the bearings, and this was brought about by settlement of the masonry supporting the machine. In order that bodies in rapid rotation upon very long shafts supported by several bearings may turn easily without vibration, it is indispensable that the principal axis of inertia of each part should coincide with the axis of rotation, and the bearings must be in correct alinement. In spite of these difficulties it has been possible to build good direct-current dynamos for direct coupling to turbines, and when the voltage is high the problem is simpler. Owing to the high peripheral velocity of the commutator it is usually necessary to employ metallic brushes, but in certain cases,

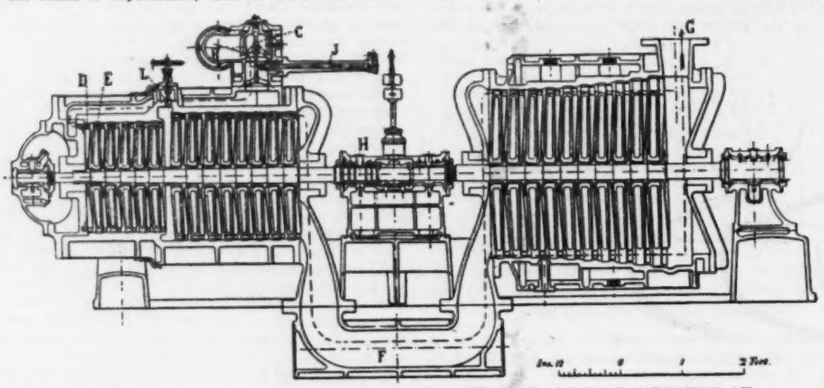


FIG. 5. LONGITUDINAL SECTION OF 500 E. HP. RATEAU TURBINE GENERATOR AT PENARROYA MINES, SPAIN.

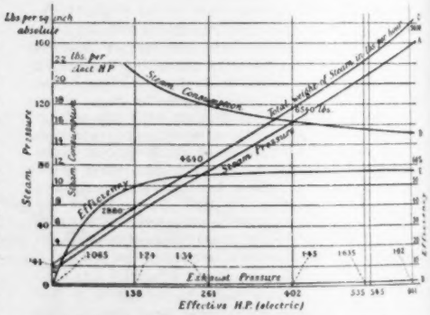


Fig. 6. Diagram Showing Efficiency of 500 E. HP. Rateau Turbine-Generator.

TABLE I. Tests of 500-HP. Rateau Turbine Generator.

Data.	¼ load.	½ load.	Full load.	Overload.	Overload at 2,400 rev.
Electrical HP. at brushes	135	259	525	627	641
Admission pressure, absolute, lbs. per sq. in.	46.21	76.6	136	156	156
Exhaust pressure, absolute, lbs. per sq. in.	1.24	1.33	1.63	1.82	1.82
Theoretical steam consumption of perfect engine per Hp. hour, lbs.	10.93	9.8	8.89	8.73	8.73
Actual steam consumption per electrical HP. hour at brushes, lbs.	21.3	18	15.8	15.39	14.90
Combined efficiency of the electrical generating set	0.513	0.540	0.560	0.569	0.580

*These results were published for the first time in the 'Annales des Mines de Paris," in February, 1897, and since that date have on many occasions been republished in various French and foreign publications.

TABLE II.—Tests of Yarrow & Co.'s Torpedo Boat. Trials of January 19, 1904.

		I.	II.	III.	IV.
Number of Trial					
Effective pressure of steam on admission to h.p. turb., lbs. per sq. in.		50	100	150	170
Condenser vacuum	ins.	28	27.5	27	27
Speed of vessel (two runs)	knots	15.58	19.25	23.22	25.714
		20.00	23.53	26.67	27.067
Mean speed of vessel	knots	17.79	21.39	24.94	26.39
Rotation of reciprocating engine	r. p. m.	458	508	555	576
Rotation of H.P. turbine	r. p. m.	836	1,052	1,207	1,258
Rotation of L.P. turbine	r. p. m.	836	1,065	1,232	1,307
Slip of propellers, per cent: Reciprocating engine		28.7	22.4	17	15.3
H. P. turbine		13.6	17.4	16.4	14.8
L. P. turbine		24.0	28.2	27.8	27.8

notably with turbines supplied by steam at low pressure when the angular velocity is lower it has been possible to use carbon brushes. The machine at Bruay, which will be referred to later on, is an example. Among other sets for direct current built by Messrs. Sautter-Harlé may be mentioned one of 500 HP. for Huta-Bankowa (Russian Poland), which is interesting from the fact that the two portions of the turbine and the two dynamos were built on two parallel shafts. This arrangement offers the advantage that one of the halves of the group can be used if the other is accidentally damaged.

TURBINES WITH ALTERNATORS.—The construction of generators for two-phase and three-phase current for direct driving by turbines offers much less difficulty than the design of direct-current dynamos for the same purpose. The absence of the commutator renders possible higher angular velocities for alternators than for direct-current dynamos. Three types of alternators have been tried successively. The machine with the solid rotor, that with the rotating field magnet and that with the rotating armature. The first type would be, from a mechanical point of view, the ideal generator for coupling to a steam turbine. Unfortunately from its design it is impossible to use speeds higher than 1,500 revolutions per minute for a frequency of 50 periods per second. On the other hand, this type of machine permits much greater magnetic leakage than the others, and this necessitates disproportionately large dimensions and a comparatively low efficiency. These circumstances are unfortunate, for the alternator with the solid rotor would permit of making the movable part of very solid construction which is easy to balance once for all and thus avoid any chance of mishap. It is on these grounds that types of alternators with revolving field-magnates or revolving armature are in actual use, and Messrs. Sautter-Harlé have already built a great number of them. A turbo-alternator with revolving field-magnets to develop 400 E. HP. at 5,500 volts is now working in the generating station of the Loire Electricity Co. The moving part of this machine makes 3,000 revolutions per minute. The results of tests have been as follows:

Pressure of steam, lbs. absolute	170
Back pressure of the exhaust, lbs.	2.85
Output of the terminals, E. HP.	388
Consumption of steam per electrical horse-power, including excitation, lbs.	19.2
Combined efficiency, per cent.	48.7

The efficiency obtained could have been much improved by increasing to a slight extent the dimensions of the turbine which had only twelve moving wheels, but even now it is comparable with turbine sets of the same power of other types. Three similar sets working with superheated steam are now being constructed for the factories of Pavin de Lafarge at Teil (Ardèche). The results guaranteed by the makers are as follows:

Pressure of steam on admission to the turbine, lbs.	156
Vacuum in the condenser, ins.	28
Temperature of the steam, degrees C.	270
Consumption of steam per electrical horse-power at the terminals, including excitation, lbs.	15

All these different machines are fitted with ejector condensers.

A machine of 2,000 KW. at 1,500 revolutions per minute would have a turbine efficiency of 68%, which would enable the following guarantee to be given, assuming the use of superheated steam and the condenser giving a very good vacuum, which it is easy to obtain with steam turbines in which there is no entrance for the air:

Pressure of steam on admission to the turbine, lbs.	200
Vacuum in the condenser, ins.	29
Temperature of the steam, degrees	350
Consumption of steam per horse-power hour upon the shaft of the turbine, lbs.	8.5

This is a far better result, we believe, than can be given by reciprocating engines, and this can be obtained with steam turbines under the conditions specified.

TURBINES FOR VESSELS.—The author read a paper on March 25 last in London before the meeting of the Institution of Naval Architects upon the application of steam turbines to the propulsion of vessels. He then described the difficulties which occur in the application of turbines to the propulsion of vessels, which are as follows:

(1) The difficulty of adapting screw propellers to the high speeds of rotation of the turbines.

(2) The poor efficiency of turbines at low velocity.

(3) The inconvenience of the combination in stopping and approaching quays.

The author believes that the best solution will be reached in the employment of a reciprocating engine of small power and of steam turbines coupled to independent shafts so that the reciprocating engine would always be working at any speed of the vessel. Then each type of machine would be perfectly adapted to the part which it has to play and excellent results in consumption of fuel would be obtained at all speeds. The author gives below a short account of the actual results obtained by turbines in the propulsion of vessels.

A VESSEL BUILT BY MESSRS. YARROW & CO.—The vessel of Messrs. Yarrow & Co. is similar to torpedo boats of the first class usually constructed by this firm and similar, with the exception of the turbines and propellers, to the "Tarantula," upon which Parsons turbines are used. The boat is of 140 tons burden, and is provided with three propeller shafts driven simultaneously and separately by a turbine divided into two portions, and a reciprocating engine. This latter engine develops 250 brake HP. and drives a central shaft which is completely independent of the turbines. The side shafts are driven by a turbine in two parts, arranged in series and rotating in opposite directions. The reciprocaitng engine was used by us in order to obtain a velocity of 10 to 14 knots in the best conditions of consumption of coal, and so that movement astern might be easily effected. The above combination adopted by Messrs. Yarrow & Co. has given the expected results; but it is not the only possible design, and the author thinks that it would have been even more advantageous to arrange the driving mechanism so that the reciprocating engine instead of allowing its exhaust to escape directly to the condenser should pass it into the turbine at low pressure and perhaps even into the turbine at high pressure during a slow speed run. The turbine of the Yarrow boat can develop more than 2,000 HP. At the points where the shaft passes through the frame tightness is obtained by a system of special packing, the same as that employed upon land turbines. A special governor assures constant pressure upon the four packings so as to prevent all entrance of air, and owing to this arrangement it is quite easy to obtain an excellent vacuum in the condenser. Several tests were made upon this vessel between Oct. 13, 1903, when it first went out and the present date. The test made on Jan. 19, 1904, after the propellers had been improved is given in Table II. The speed of 25 knots which had been attained in the first trial of the boat has been increased to 26.39 knots by giving to the turbines a little more than the quantity of steam for which they were designed.

The propeller shafts were for this test each fitted with two propellers. The author's opinion on this subject is that the use of a single propeller upon the same shaft is certainly likely to give a better efficiency. The arrangement of propellers, one in front of the other is defective. The aft propeller works in the moving tail water from the former. It is certain that the speed of 26.4 knots can be still further improved and will become equal or even higher than the maximum speed given by reciprocating engines. The use of a single propeller for each shaft necessitates a peripheral diameter greater than the pitch in order to obtain sufficient propulsive surface. Under such conditions the efficiency can never be good unless the inclination of the shafts to the horizontal is very slight. In spite of this it is probable that the efficiency of these propellers with a relatively small pitch is distinctly less than that of ordinary propellers. Fortunately, this inferiority can be compensated by the fact that the efficiency of well-designed turbines is a little higher than that of the reciprocating engines used on board ship.

TURBINE-DRIVEN PUMPS.—The application of steam turbines for the purpose of direct driving of centrifugal pumps enables most remarkable results to be obtained and particularly renders possible height of lifts much greater than those which are at present obtained. It is well known that the pressure produced by the wheel of a centrifugal pump increases directly as the square of the peripheral speed, and therefore with the velocity produced by steam turbines it becomes possible with a single wheel to raise large volumes of water to heights of more than 900 ft. in a single lift. If it is desired to obtain either greater pressures or to obtain the same results with relatively lower speeds it is sufficient to couple steam turbines with pumps consisting of several similar wheels arranged in series so that each one increases by an equal quantity the pressure already given by the preceding wheels. Multicellular turbine pumps form very light sets, which are compact and extremely simple. Their maintenance is very low for the wear is almost nil and the cost of lubricating oil extremely small. In the example referred to below it will be seen that the consumptions of steam per brake horse-power in water raised are comparable with those of good piston pumps.

TURBO-DRIVEN PUMPS AT BRUAY.—A powerful turbo-pump has been made and delivered recently to the Mining Co., of Bruay, in the Pas-de-Calais. This set can raise 950 gallons a minute to a height of 1,200 ft. The complete set mounted above a small tank into which discharges the ejector-condenser, which is used for condensing steam, and from which is taken the suction of the principal pump. At the end of the shaft is a small pump, which is directly coupled to the turbine, and furnished water to the ejector-condenser at a pressure equivalent to a head of 18 to 20 ft. The results obtained with this pump at full load were as follows:

Discharge in gallons per minute	980 gals.
Total lift	1,195 ft
Revolutions per minute	2,200
Absolute pressure of the steam on admission to the turbine	101 lbs.
Absolute back pressure at the exhaust	1.61 lbs.
Brake horse-power of the set	350 brake HP.
Consumption of steam per brake HP. per hour in water raised	22.7 lbs.
Total net efficiency	42.5%

It will be observed that the total efficiency of this set is very high, attaining to 42.5%. One of the chief advantages of turbo pumps, besides their excellent efficiency, is the extremely small floor space which they occupy when compared with piston pumps. Their dimensions are very small, and they require very little height, so that they can be placed in a room which has no greater dimensions than that of an ordinary working gallery in a pit.

TURBO PUMPS FOR BOILER-FEED PURPOSES.—This class of pump can be used very readily for feeding steam boilers, and several such sets have already been constructed. When there is a group of generators of the same size, a turbo pump can easily carry out the whole feed service with a consumption of steam much less than that of the small feed pumps usually employed. Whilst ordinary reciprocating pumps consume from 150 to 250 lbs. of steam per brake horse-power in water moved, the turbo pump for boiler-feed service will not usually requite more than 40 to 60 lbs. per brake horse-power. An automatic system of control has been designed by the author which enables the apparatus to work automatically in a continuous manner even when the demand falls to zero. The work of the stoker, so far as the feed service is concerned, consists simply in operating the feed valve to the necessary amount.

TURBO PUMPS OF LARGE OUTPUT FOR RAISING WATER IN TOWNS.—Turbo pumps, both from the point of view of efficiency and also of ease in working, are particularly suitable for raising water into reservoirs for the service of towns. The following figures indicate results which have been obtained with this class of machine in similar conditions to those that exist in large towns.

Delivery in gallons per minute	5,200
Height to which the water is raised	460 ft.
Actual horse-power in water raised	730 brake HP.
Combined efficiency including condensation	46%
Pressure of steam in pounds per square inch	210
Vacuum at the exhaust	28 ins.
Superheat in the steam	100°
Consumption of steam per brake horse-power hour in water raised	15 lbs.

It will be observed that the system described is quite as efficient as the best piston pumps now employed.

TURBO FANS.—The great angular velocity of steam turbines makes them particularly suitable for the direct driving of fans for high pressure used for blowing engines and even for air compressors. A set, which is now actually at work in the forges of Chatillon et Commentry, is used for blowing a blast furnace. The set consists of two fans arranged in parallel and each driven by one turbine (the two turbines are placed in series) and the apparatus will discharge 80 cu. ft. of air per second under a pressure of 10 ins. of mercury. The energy in the compressed air rises as high at 100 HP. The moving wheels of the fans and of the turbines are only 11.2 ins. in diameter, and Table III gives an abstract of the results of trials to which the apparatus was submitted.

It will be seen from this table that the combined effi-

TABLE III.

Test of Turbo Fan at Commentry. August 6-8, 1903.

Orifice.	Revs. per Minute.	—Pressure of Steam— Absolute. Admission.	Exhaust.	Air pressure at Fan.	Total Air Discharge.	Air Discharge.	HP. Theoretical.	HP. Useful.	Total Efficiency.
sq. ins.		lbs. per sq. in.	lbs. per sq. in.	Feet of water.	lbs per hour.	Cubic ft. per sec.			
19.1	15,200	113.8	4.53	10.60	3037	91.4	260.4	99	0.380
	15,700	128.0	4.80	11.61	3403	93.5	299.5	112.6	0.377
22.8	14,600	113.8	4.92	9.0	3037	99	256.9	93.2	0.363
	15,200	128.0	5.32	9.90	3403	103	289.6	106.52	0.368
	15,800	142.2	5.68	11.0	3790	107.5	327.2	121.91	0.372
27.8	14,300	113.8	4.44	7.55	3037	114	261.8	91.08	0.348
	14,900	128.0	4.80	8.25	3403	117.5	299.5	102.46	0.342

ciency of the apparatus reaches the remarkable figure of 38%. Similar apparatus of larger dimensions can be built, and these might replace advantageously the large blowing engines used for blast furnaces. One important characteristic of these sets is their remarkably small dimensions, and they can be put down at an expense which is very small in comparison to large piston blowing engines. By coupling several wheels of centrifugal fans, as we couple the wheels of multicellular pumps, much higher pressures of air can be obtained. In a few months we shall finish the construction of a centrifugal turbine compressor of 350 HP. capable of delivering compressed air at a pressure of 90 lbs. per sq. in. This apparatus will be driven by a low-pressure turbine using the exhaust steam from a winding engine used in a pit. The turbine has as a stand-by a high pressure turbine so as to ensure economical working during the time when the winding engine is out of use. This special branch of the application of steam turbines to air-compression has, in our opinion, a great future, not only for work in mines, but also in metallurgy, where blowing engines of all kinds for blast furnaces and for the tuyeres of steel works may be replaced by the centrifugal machines of a much simpler and smaller character, costing far less and requiring less repairs than the present piston engines.

TURBINES FOR LOW PRESSURE WITH STEAM ACCUMULATORS.*—One of the most interesting and promising applications of steam turbines is the employment of steam at low pressure, and particularly exhaust steam coming from engines working intermittently. The author has given special attention to the interesting problem of the employment of such waste steam, and he has obtained satisfactory results by means of his regenerative accumulator of steam, combined with turbines at low pressure, which are themselves coupled directly to dynamos, centrifugal pumps, or fans. The regenerative accumulator is intended to regulate the intermittent flow of steam before it passes to the turbine, and it consists essentially of a vessel containing solid and liquid materials which play the part of a fly-wheel for heat. The steam collects and is condensed as it arrives in large quantities in the apparatus, and is again vaporized during the time when the exhaust of the principal engine diminishes or ceases. The necessary variations for condensation and regeneration of the steam correspond to fluctuations in pressure in the accumulator, this pressure rising when the apparatus is being filled and descending when it is discharging into the turbine. Water which has a very high calorific capacity has been used as a heat flywheel, but in order to rapidly communicate to a liquid mass a considerable quantity of heat corresponding to the latent heat of steam to be condensed it becomes necessary, owing to the poor conductivity of water, either to arrange it in thin layers or to cause a rapid circulation in order to increase the surface of contact between the steam and the water itself. The first solution of the problem gave rise to the accumulator with flat cast-iron trays in which water is contained in shallow vessels arranged one above the other. The second solution of the problem gave rise to the accumulator with water only in which a rapid circulation was produced by the injection of steam into the body of the liquid itself. The low pressure turbine, fed by the regular flow which comes from the accumulator, and working, for example, between an admission pressure of 15 lbs. per sq. in. and a vacuum at the condenser of 27 ins. of mercury (back pressure of 1.6 lb.) can furnish an electric horse-power for about 31 lbs. of steam per hour. In a moderate sized mine, consuming 13,000 lbs. steam per hour, it is, therefore, possible to economize under these conditions about 350 E. HP. In steel works, where reversible steam rolls are employed consuming about 45,000 lbs. of steam per hour, it will be easy to develop, by means of accumulators and turbines, an extra output of over 1,100 E. HP. It is desirable to mention that the steam engines are in no way injuriously affected in their working by the presence of the accumulator and turbines. This method was applied for the first time at Bruay, and the installation has worked most satisfactorily since August, 1902, when it was first put into use. The exhaust steam from a winding engine is first of all treated by an accumulator with cast-iron trays, [illegible] to a low pressure turbine of 300 HP. wi[illegible] two dynamos keyed upon the same shaft. A [illegible] ure of this type of installation is the [illegible] pander," which comes into use when the [illegible] is not giving sufficient steam, and also w[illegible] is not working. This apparatus then [illegible] mission to the turbine of live steam which [illegible] the boilers through reducing valves; th[illegible] be adjusted by means of a spring, and [illegible] as soon as the pressure falls below a [illegible] point.

This system of regulation by means of [illegible] lators and turbines, which is particularly [illegible] mines and steel works, enables very consid[illegible] to be effected. Installations of this natu[illegible] course of erection at the following places:

350 HP. at the Béthune mine (turbine-d[illegible] pressor).

600 HP. at the Steel Works of Reunion in [illegible] generating sets).

2,000 HP. at the Donetz Steel Works (electric generating plant).

700 HP. at the Acieries de Poensgen à Dusseldorf (electric generating plant, etc.).

As the author showed in a note published in January, 1904, in the "Revue Universelle des Mines," this system offers great advantages when there already exists a central condensing plant, and the Poensgen installation is being carried out in that manner.

*Proceedings, 1901, p. 945.

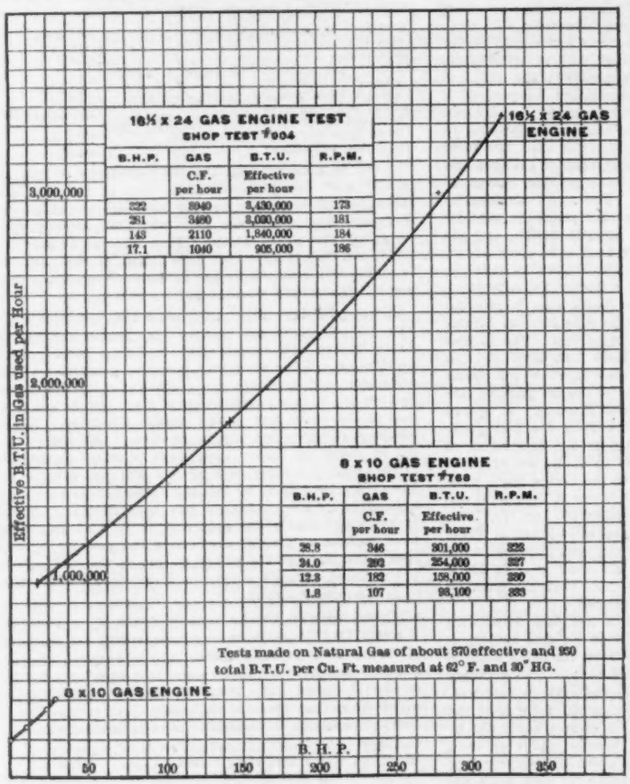

16½ x 24 GAS ENGINE TEST
SHOP TEST #904
B.H.P. | GAS C.F. per hour | B.T.U. Effective per hour | R.P.M.
322 | 3040 | 3,430,000 | 173
281 | 3480 | 3,030,000 | 181
143 | 2110 | 1,840,000 | 184
17.1 | 1040 | 905,000 | 186
8 x 10 GAS ENGINE
SHOP TEST #768
B.H.P. | GAS C.F. per hour | B.T.U. Effective per hour | R.P.M.
28.8 | 346 | 301,000 | 328
24.0 | 292 | 254,000 | 327
12.3 | 182 | 158,000 | 330
1.8 | 107 | 93,100 | 333
Tests made on Natural Gas of about 870 effective and 950 total B.T.U. per Cu. Ft. measured at 62° F. and 30" HG.
16½ x 24 GAS ENGINE
8 x 10 GAS ENGINE
Effective B.T.U. in Gas used per Hour
3,000,000
2,000,000
1,000,000
B. H. P.
50
100
150
200
250
300
350

FIG. 1.

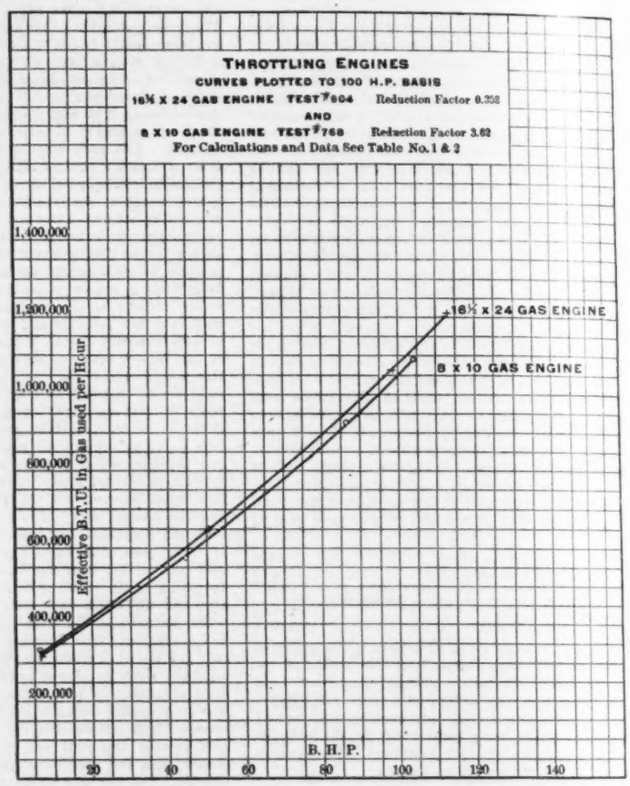


FIG. 2.

TABLE I.—Data and Calculations for Fig. 1.

16½ × 24 Gas Engine—Test No. 904.

Type—Horizontal, double-acting, tandem, single crank, four-cycle throttling engine.	
Diameter of cylinders	16½ ins.
Stroke	24 "
Diameter of piston rod (in three explosion chambers)	5⅝ "
Diameter of tail rod (in one explosion chamber)	2⅝ "
Full load test speed	181 R. P. M.
Number of charges per two revolutions	4
Suction displacement per minute	981 cu. ft.
Deduction factor = 345 cu. ft. / 981 cu. ft. =	0.352

Actual readings.	Readings calculated to 100 HP. basis.
322 B. HP. 3,430,000 B. T. U.	113.3 B. HP. 1,207,000 B. T. U.
281 B. HP. 3,030,000 B. T. U.	99.0 B. HP. 1,066,000 B. T. U.
143 B. HP. 1,840,000 B. T. U.	50.3 B. HP. 646,000 B. T. U.
17.1 B. HP. 905,000 B. T. U.	6.0 B. HP. 318,000 B. T. U.

Note.—The second column of figures are obtained by multiplying those in the first column by the reduction factor 0.352.

TABLE II.—Data and Calculations for Fig. 2.

8 × 10 Gas Engine—Test No. 768.

Type—Single-acting, two-cylinder, four-cycle, vertical throttling engine.	
Diameter of cylinders	8 ins.
Stroke	10 "
Full load test speed	327 R. P. M.
Number of charges per two revolutions	2
Suction displacement per minute	95.2 cu. ft.
Reduction factor = 345 cu. ft. / 95.2 cu. ft. =	3.62

Actual readings.	Readings calculated to 100 HP. basis.
28.8 B. HP. 301,000 B. T. U.	104.0 B. HP. 1,090,000 B. T. U.
24.0 B. HP. 254,000 B. T. U.	87 B. HP. 920,000 B. T. U.
12.3 B. HP. 158,000 B. T. U.	44.5 B. HP. 573,000 B. T. U.
1.8 B. HP. 93,100 B. T. U.	6.5 B. HP. 337,000 B. T. U.

Note.—The second column of figures are obtained by multiplying those in the first column by the reduction factor 3.62.

CONCLUSION.—There is no need to insist upon the well known advantages of turbines resulting from their absolutely steady motion, but, on the contrary, the enormous speed at which they must work in order to suit the velocity of flow of the steam is, in many cases, a serious inconvenience, particularly in the application of the turbine to the propulsion of vessels. It was a similar disadvantage for a considerable time in the driving of dynamos, but now it is possible to construct dynamos for very high speeds, and these can be coupled to steam turbines forming light and inexpensive sets which take up little room, although they are very powerful. Such sets are very simple and are very easy of maintenance. Besides the constant value of the turning effort, the chief advantages which can be claimed for steam turbines may be thus summarized: very low consumption of steam, particularly at small loads. From this point of view they are notably superior to piston engines of even the best-known type. Further advantages are the small floor space occupied and the absence of expensive foundation work; the cost of oil is very low, particularly for our turbines, which have oil reservoir and ring lubrication to all the bearings. The oil in the reservoir need be changed only once in two months, and it is not thrown out by the rotating parts, so that the machinery always remains clean. With steam turbines momentary or even permanent overloads are very easy to deal with. It is even quite possible to have overloads of more than 50% higher than the normal load. The regulation of speed in steam turbines is carried out in a more perfect manner than is possible for piston engines, and this is due, on the one hand, to the absolute constancy of the turning effort, and, on the other part, to the great kinetic energy accumulated in the revolving parts. This last characteristic makes the machines very insensible to variations in load. The full load may be taken off and put on again without causing a variation in speed of more than 2 to 3%. When coupled to dynamos, fans or centrifugal pumps, steam turbines render it possible to obtain surprising results owing to their capability of giving great power at very high speeds. The author has constructed turbine-driven fans, giving a pressure of 7.5 lbs. per sq. in., and turbine-driven pumps raising water to several hundred meters. Such sets can now be built to develop several thousand horse-power, compressing air to more than 90 lbs. per sq. in., or raising water to more than 2,000 ft. high. Turbines are able to use to perfect advantage steam at low pressure, for they have an efficiency rising in value as the pressure of the steam becomes lower. In combination with steam accumulators of the type designed by the author of this paper, turbines permit of the employment of exhaust steam in large quantities produced by engines working intermittently, such as winding engines and engines used in metallurgical works. It will be seen that their field of application of steam turbines is very wide, and it is certain that a great future is in store for them.

COMMERCIAL GAS ENGINE TESTING AND A PROPOSED STANDARD OF COMPARISON.*

By William P. Flint,† M. Am. Soc. M. E.

The value of accurate and comprehensive testing of all prime movers, and the determination of a basis of comparison upon which to judge the relative economy of those of any particular class cannot be overestimated. To the manufacturer of heat motors, especially, it is unquestionably necessary, and at the same time most expedient, to incorporate into the scheme of engineering organization an efficient testing department, which shall at once be capable of securing accurate data of the operation of the finished machines without being burdened with any unnecessary refinements. The simplest reliable methods and apparatus are therefore obviously best suited to accomplish the desired results, and it is then left only to determine the most feasible basis upon which to make comparisons of the characteristic data obtained.

The friction brake is by long odds the most satisfactory means of measuring the power developed. Its accuracy depends on the following factors:

(1) The accuracy of standard platform scales. This is easily verified by standard weights. (2) Allowance for the weight of the blocking on the scales and the unbalanced weight of the brake band and arm. These are both easily determined by actual weighing. (3) The brake radius, or distance from center of the shaft to the knife edge supporting the brake arm. (4) The revolutions per minute. (5) The steadiness with which the scales are kept balanced. If we compare the above simply verified facts with those required by an indicator test, it will be at once apparent how much superior the brake is to the indicator as a means of quickly and reliably measuring power. Then also the available or brake horse-power, and not the indicated horse-power, is the thing for which engines are run.

In practice it is necessary to lubricate the brake wheel for the purpose of making the friction uniform, and to prevent the wooden cleats becoming locally heated and taking fire. It is found that strips of fat salt pork make the best lubricant, for they slowly fry and thus keep the wheel uniformly and continuously greased. The wheel must, of course, be cooled, and this is usually provided for by casting re-entrant lips on it, which will retain a layer of water by virtue of centrifugal force when the brake wheel is in motion. A stream of water is fed into the brake wheel at one point and scooped out by a stationary pipe at another point. By this means the temperature of the brake wheel is controlled.

When the temperature and lubrication of the brake wheel are kept constant, it is not difficult for a man with a wrench to keep the brake band tension screw so adjusted that the scale beam of the platform scales is always substantially balanced. If the load becomes too great, he slackens the tension, and if too small, he increases it.

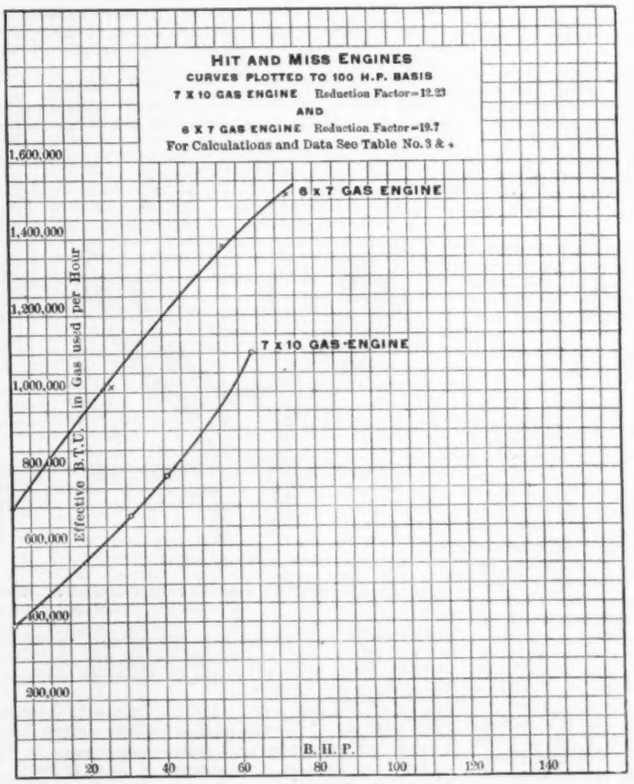


FIG. 3.

Occasionally considerable annoyance may be experienced by sudden changes of friction occurring which are due to a little water getting on to the outside of the brake wheel. This seems to chill the lubricant and have a disturbing effect out of all proportion to the cause. It is a small practical point well worth attention, for with irregular variations in the friction, the man at the brake cannot keep the load constant. The remedy is very simple—keep water off the outside of the brake wheel.

The indicator, while not as useful for power determinations, is of great value for showing what is going on in the cylinder, and cards should always be taken in connection with the brake test. It will often be superfluous to calculate the indicated horse-power from them. If engineers in charge of gas engines made more frequent use of the indicator, they would frequently be able to obtain increased satisfaction by detecting faulty adjustments, particularly of the point of ignition.

Where an engine is being tested on a constant load and quality of gas, the governor should hold the speed constant enough to warrant the use of a good make of hand-speed counter. Where the above condition is not met a continuous counter must be employed.

FOR MAKING GAS MEASUREMENTS.

A good meter, whose accuracy is checked occasionally, by means of prover tests, over the range for which it is used, is the best instrument. The temperature and pressure of the gas at the meter and the barometer reading (uncorrected for sea-level) are needed for correcting the meter readings to standard conditions. Calorimeter determinations or chemical analyses, will give the heat value of the gas.

COMPARISON OF TESTS.—After tests are made we still desire to know what they mean. We must have a standard with which to compare the results obtained on a given engine and as a basis for predicting what that engine ought to do.

The most natural standard is the cubic feet of gas used per brake horse-power hour. When, however, we attempt to use this, we find that for each engine it is a function of the load carried. Its value varies considerably at full load, and very rapidly at light loads, until at no load it reaches infinity. We must make several tests at different loads in order to get the law of this variation. When we calculate the gas consumption per brake horse-power hour at light loads, we find that a very small variation in the total amount of the gas used, or of the load at which the test is made, makes a very large and unmeaning variation in the cubic feet per brake horse-power hour.

This unmeaning characteristic of the gas per brake horse-power curve at light loads, leads one to prefer the use of a curve plotted with the brake horse-power as abscissæ, and the cubic feet gas, or better yet the British thermal units of gas, per hour as ordinates. Fig. 4 shows two such curves, one for an 8 by 10, and the other for a 16½ × 24 gas engine. These two curves, however, are so different in size that they are incomparable with each other, even though the engines require about the same number of British thermal units per brake horse-power hour at corresponding loads. They need to be plotted to such scales that they may be readily compared. Without

TABLE III.—Data and Calculations for Fig. 3.

7 × 10 Gas Engine—No. 1307.

Type—Single-acting, single-cylinder, four-cycle, horizontal, hit and miss engine.

Diameter of cylinders	7 ins.
Stroke	10 "
Full load test speed	253 R. P. M.
Number of charges possible per two revolutions	1
Suction displacement per minute	28.2 cu. ft.
Reduction factor = 345 cu. ft. / 28.2 cu. ft. =	12.23

Actual readings.	Readings calculated to 100 HP. basis.
5.22 B. HP. 90,500 B. T. U. 250 R. P. M.	63.8 B. HP. 1,108,000 B. T. U.
3.35 B. HP. 63,000 B. T. U. 253 R. P. M.	41 B. HP. 778,000 B. T. U.
2.60 B. HP. 55,200 B. T. U. 255 R. P. M.	31.8 B. HP. 675,000 B. T. U.
0 B. HP. 32,400 B. T. U. 256 R. P. M.	0 B. HP. 396,000 B. T. U.

Note.—The second column of figures are obtained by multiplying those in the first column by the reduction factor 12.23.

TABLE IV.—Data and Calculations for Figure. 6.

6 × 7 Gas Engine—No. 1141.

Type—Single-acting, single-cylinder, four-cycle, horizontal, hit and miss engine.

Diameter of cylinder	6 ins.
Stroke	7 "
Full load test speed	306 R. P. M.
Number of charges possible per two revolutions	1
Suction displacement per minute	17.52 cu. ft.
Reduction factor = 345 cu. ft. / 17.52 cu. ft. =	19.7

Actual readings.	Readings calculated to 100 HP. basis.
3.76 B. HP. 770,000 B. T. U. 305 R. P. M.	74.0 B. HP. 1,515,000 B. T. U.
2.90 B. HP. 698,000 B. T. U. 306 R. P. M.	57.3 B. HP. 1,375,000 B. T. U.
1.36 B. HP. 513,000 B. T. U. 316 R. P. M.	26.8 B. H. P. 1,010,000 B. T. U.
0 B. HP. 357,000 B. T. U. 327 R. P. M.	0 B. HP. 703,000 B. HP.

Note.—The second column of figures are obtained by multiplying those in the first column by the reduction factor 19.7.

*A paper presented at the Chicago meeting of the American Society of Mechanical Engineers.

†Engineer, Gas Engine Department, Westinghouse Machine Co., E. Pittsburg, Pa.

replotting, however, they give at a glance the British thermal units required on each engine at any load and from them the British thermal units per brake horse-power hour curves may be readily derived.

PROPOSED BASIS OF COMPARISON.—The maximum power of a given gas engine depends on the number of British thermal units it can take in per minute, and on the percentage of this heat which it can turn into brake horse-power.

With engines of about 10 brake horse-power per cylinder and larger, there is but little variation in the efficiency of similar engines, which may be attributed to the size. The consequence of this is that the power of gas engines of the four-stroke cycle type varies almost in proportion to their suction displacement, and some one size of engine may be taken as a standard to which to reduce the figures obtained on other engines. The curves thus obtained from the results of tests on many sizes of engines are mutually comparable. They furnish a basis for predicting what still other sizes of engines, not yet tested, may be expected to do.

The results of tests on a large number of similar engines using natural gas for fuel have shown that every 345 cu. ft. mixture displacement per minute will give in the neighborhood of 115 maximum brake horse-power, or 100 rated brake horse-power.

The above displacement is figured from the area of the piston, length of stroke, and the greatest number of charges per minute at full load speed, and furnishes the data upon which it is proposed herein to establish a basis of comparison.

Fig. 2 shows the two curves given in Fig. 1 replotted to this new basis. The necessary calculations are very simple, and are given in Tables No. I and II. The British thermal units per brake horse-power hour for any load may be obtained by dividing the British thermal units reading by the corresponding brake horse-power reading. This is particularly simple at the 100 HP. load when it simply means pointing off two places of the British thermal units reading.

Tests plotted in this way show up graphically the relation between the power developed per unit of mixture displacement in different engines, as well as the relative economy in gas consumption. By plotting in this manner, the results of a large number of tests of gas engines, a manufacturer can ascertain the characteristic British thermal units brake horse-power curve for each size and type, and from these can predict what new sizes should do. Experience teaches that when reduced to a common basis, there is but little more variation between the curves for similar engines of different sizes than between individual engines of the same size. There are so many factors influencing the exact location of the curves in question, that under commercial conditions, a good many tests have to be run before safe average curves can be drawn. For this reason it is most helpful to be able to readily and intelligently compare the results of different sizes, to the end that the experience gained on a size of which many engines have been built may be utilized in criticising the performance of a new size. The average curves thus determined may, with good advantage, be replotted in a manner similar to Fig. 1, for the use of agents who need to be able to quickly answer questions as to the total amount of gas which a given engine will use at each of several different loads.

Fig. 3 shows the results obtained on two small, "hit and miss" gas engines plotted to the 100 HP. basis, and is given to illustrate the effectiveness of the graphical comparison of tests on engines showing very different efficiency and capacity per unit of mixture displacement. These engines have low compression, which has a good deal to do with the poor performance shown.

Besides enabling an average performance curve to be located with considerable certainty, this 100 HP. basis method lends itself well to the determination of limiting curves and figures between which the performance of any engine may be expected to lie. This is often very useful in drawing attention to defects in an individual engine, and in detecting errors which occasionally may be made in shop tests. It should prevent defective engines from being sent out, and also prevent unusually good or poor records being entered without the careful verification which they should receive.

RELATION OF MIXTURE DISPLACEMENT TO POWER AND EFFICIENCY OF THE ENGINE.

It is interesting in this connection to do a little guessing as to what factors are involved in the above relation for the standard 100 HP. engine here proposed.

It will, by assumption, have a nominal mixture displacement of 345 cu. ft. per minute at full load speed and a maximum power of 115 brake HP. The overload speed will be less than that at full load, and if we assume it 2% less, we shall have 98% of 345 or 338 cu. ft. actual displacement per minute at overload. The exhaust gases in the clearance spaces are often at a slight pressure at the end of the exhaust stroke, and have to expand to atmospheric pressure before any new charge is sucked in. Again, there is usually a slight vacuum at the end of the suction stroke. Light spring stop motion cards taken to show plainly the suction and exhaust lines indicate that there may be a loss of about 5% of the displacement volume. Then 95% of 338 cu. ft. equals 321 cu. ft. and gives the actual suction displacement filled with new gases per minute. This 321 cu. ft. of mixture is measured at a temperature above that of the atmosphere, due to the heat absorbed from the cylinder walls and to the admixture of hot gases left in the clearance space from the previous explosion.

It must be admitted that the author has no data at hand for arriving at a fair figure for this temperature, other than that of assigning it such a value as will make the final result seem reasonable. By assuming this temperature to be 210° F., or 671° F., absolute, the correction becomes $\frac{523}{671} = 78\%$, which means that 250 cu. ft. of mixture per minute at standard pressure and temperature are drawn in.

The next question is the number of heat units which this 250 cu. ft. of mixture contains. To simplify the calculation consider the gas to be all CH_4. This is so nearly true of natural gas that the results are applicable also to it.

$$CH_4 + 2\,O_2 + 7.50\,N_2 = CO_2 + 2\,H_2O + 7.50\,N_2$$

is the equation for the theoretical explosive mixture, but we must have an excess of air present or some gas will not be burned. Here again it is necessary, in the absence of measurements of the volume of air used, to resort to an arbitrary assumption and add 10% excess of air. The equation then becomes

$$CH_4 + 2.2\,O_2 + 8.25\,N_2 = CO_2 + 2\,H_2O + 8.25\,N_2 + 0.2\,O_2 \text{ or}$$
$$CH_4 + 10.45 \text{ air} = CO_2 + 2\,H_2O + 8.25\,N_2 + 0.3\,O_2$$

1 cu. ft. CH_4 gives 1,015 total British thermal units, or (allowing for the heat of vaporization of water formed which is not available for power purposes in any gas engine) 915 effective British thermal units per cu. ft. of gas. 1 cu. ft. gas + 10.45 cu. ft. air contains 915 effective B. T. U., or we have $\frac{915}{11.45} = 80$ effective B. T. U. per cu. ft. of mixture. Thus the 250 cu. ft. of mixture per minute will contain 80 × 250 = 20,000 effective B. T. U.

The assumption at the start of this calculation was that the engine would give 115 maximum brake HP., and as 42.4 B. T. U. per minute is the theoretical equivalent of 1 brake HP. minute, this means that 115 × 42.4 = 4,870 B. T. U. out of 20,000 B. T. U. per minute are transformed into brake HP.; that is, the B. T. U. equivalent of brake HP. divided by effective B. T. U. equals $\frac{4,870}{20,000}$ = 24.35% efficiency. This efficiency means 10,430 effective B. T. U. per brake HP. hour, and is what is obtained in practice under good conditions.

It is not claimed that this calculation represents the results of particular tests. It is given only to draw attention to the factors which are involved in the relationship existing between the displacement, power and efficiency of the engine here assumed as a basis for comparison. Incidentally this reasoning indicates a line of laboratory experiments which may throw light on the temperature of the gases at the beginning of compression, since that is the only factor in the series which cannot be quite readily measured.

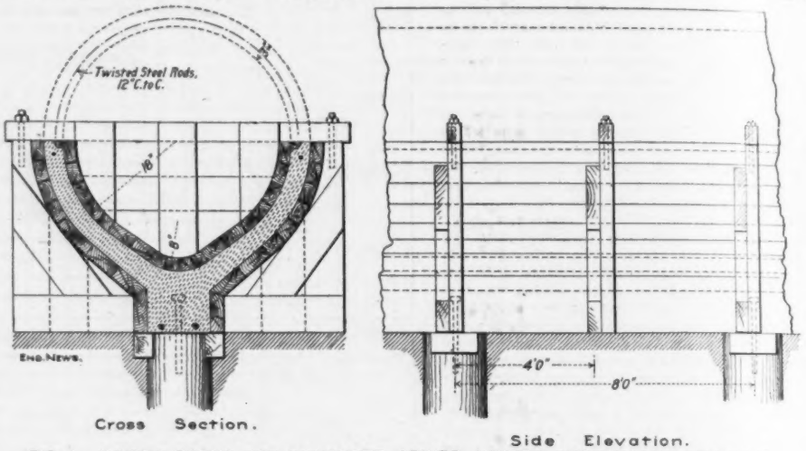
This system of plotting the results of gas engine tests to a common basis has proved so helpful in the study of one well-known make of gas engine, and is so simple of application, that it is commended to the attention of all engineers interested in this subject, and it is hoped that those who publish tests on important engines will take readings on several different brake loads, including the maximum, and will give the few easily determined facts about the engine which are needed by those who wish to plot the data as herein proposed.

FORMS FOR CONSTRUCTING A 36-IN. REINFORCED CONCRETE SEWER AT BEVERLY, MASS.

By Geo. P. Carver, C. E.*

Part of the sewer system to be installed by the United Shoe Machinery Co. in connection with its new plant, in Beverly, Mass., is to be laid in a fill which was made on 5 or 6 ft. of mud in the bottom of the Bass River, which is now dammed up. To insure this pipe from settling and to keep its alinement, it has been decided to install a reinforced concrete sewer, the lower part of which will be in a reinforced concrete beam about 10 ins. square. The whole to rest on a single line of piles driven to the proper depth and spaced 8 ft. on centers, as shown by the drawings of Fig. 1.

It will be seen from the accompanying plan what has been devised as a means for constructing this line of pipe, which has an inside diameter of 36 ins. The trench will be excavated from 8 to 10 ft. deep, which will be 1 to 3 ft. below grade line of top of piles, and backfilled to this grade, tamped and rammed to support the forms. Between the piles the backfilling will receive the concrete for the beam. A block is secured to top of the piles to support the lower forms.



Cross Section. Side Elevation.

FIG. 1. INVERT FORMS FOR CONCRETE SEWER, UNITED SHOE MACHINERY CO.'S WORKS, BEVERLY, MASS.

The forms will be made entirely of 2-in. lumber and will be in 8-ft. lengths, with a rib at each end and one in the center. The forms will be placed in position and secured by stakes and other means to the bottom and sides of trench. Before the suspended form is put in position the beam with its rods will be poured up to within 1 or 2 ins. of the flow line, when the inside form will be suspended, and the balance of the lower half of the pipe poured. The inside form is constructed 8 ft. in length, with a rib at each end and one in the center. The upper piece of the rib is a 2 × 3-in. piece extending out beyond ribs of the lower form, to which it is secured by being set over bolts secured to the lower rib, and kept secure with nuts. To the upper strip of lagging on the inside form is fastened a strip 1¼ × 1 in. to form a joint into which the upper half of pipe is set. When the lower half is completely poured and set, the forms will be removed and the backfilling brought up to within 2 or 3 ins. of the top of the concrete.

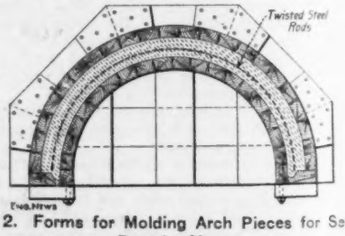


Fig. 2. Forms for Molding Arch Pieces for Sewer, Beverly, Mass.

It is intended to cast the upper part of the pipe in suitable forms (Fig. 2) in 2-ft. lengths, and place the same in position after they are set. These pieces will be reinforced with ¼-in. steel rods placed 1 in. on centers.

*United Shoe Machinery Co., Beverly, Mass.

THE DE LAVAL STEAM TURBINE.*

By E. S. Lea,† M. Am. Soc. M. E., and E. Meden.

The fundamental principles of the De Laval Steam Turbine are clearly shown in Fig. 1. It is a pure impact turbine, with a single turbine wheel, carrying one row of buckets, to which the steam is delivered in free jets at the highest possible velocity. These steam jets come from stationary nozzles, tapered so as to increase their cross sectional area toward the outlet end of the nozzle, and so calculated that the steam, before leaving the nozzle, has fully expanded down to the pressure prevailing in the exhaust chamber of the turbine, and has assumed a correspondingly high velocity, so that its whole available energy has been transformed into kinetic energy.

The velocity of the steam jets varies considerably, owing to change in pressure of the steam before entering the nozzles, to varying exhaust pressure, and to a greater or less degree of moisture or superheat in the steam. The lower limit of this velocity found in general practice might be

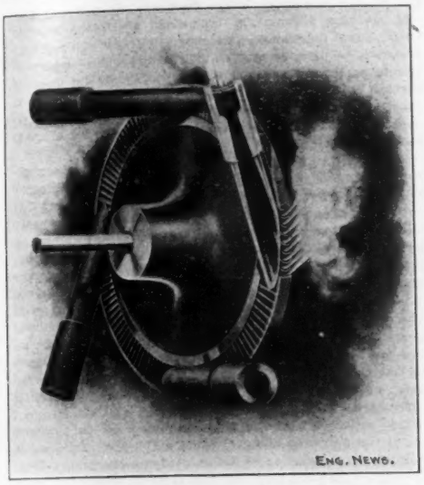


Fig. 1. The De Laval Steam Turbine Wheel and Nozzles.

considered as about 2,000 ft. per second, which is obtained at a steam pressure of about 45 lbs. per sq. in., at an exhaust pressure equal to the atmospheric pressure, and with steam containing 10% of moisture. The upper limit is found to be about 4,400 ft. per second, at a steam pressure of 200 lbs. per sq. in. at 27.5 ins. vacuum, with the steam superheated 200° F. The velocity of the steam will determine the conditions under which a maximum of the transformation of the steam jets' kinetic energy into useful mechanical work can be reached, these conditions being the same as for impact water turbines.

The nozzle angle, or the angle of the steam nozzle with relation to the plane of the wheel, should be as small as possible. A certain mathematical relation should exist between the nozzle angle, the velocity of the steam jet, the peripheral velocity of the turbine wheel, and the inlet angle of the buckets. The outlet angle of the buckets should be the smallest possible. Practical considerations limit to a certain degree the attainment of proper angles for the very best efficiency. Thus, in the De Laval turbine, a nozzle angle of 20° has been established for all sizes of the turbine, the inlet and outlet angles of the buckets are made alike, and are 32° for smaller sizes, 38° for larger sizes. With these angles fixed, and taking into consideration the thickness of the buckets, it will be found that the best theoretical peripheral velocity of the turbine wheel will be about 950 ft. per second for a steam jet velocity of 2,000 ft. per second, and about 2,100 ft. per second for a jet velocity of 4,400 ft. per second.

Contrary to popular belief, there are no reasons, either theoretical or practical, to prevent the building of a safe turbine wheel, with a peripheral velocity as high as 2,100 ft. per second; only economical reasons have put a limit to it. In the turbines that have been built, the actual peripheral velocity varies between about 1,400 ft. per second in the larger sizes; and about 500 ft. per second in the smaller sizes. In comparison with existing machinery and other types of steam turbines, these velocities are exceedingly high, and have necessitated the solution of some very interesting theoretical problems, such as the calculating of the strains in wheels revolving at high speeds, determination of flexible shafts suitable for carrying these wheels, etc. These theories would occupy too much space to enumerate here, and as they have been published in the technical literature, we have omitted them.

The diameters of the turbine wheels are such, in relation to the given peripheral velocities, that the speeds run from 10,600 revolutions per minute for the largest size, to 30,000 revolutions per minute for the smallest size. These speeds are reduced approximately 10 to 1, by helical gearing, giving driving shaft speeds of 900 to 3,000 revolutions per minute. A single gear wheel is provided in the smaller types, and in the larger sizes they are double, as shown in Fig. 3. If the larger types were single geared, the pressure in the pinion bearings, due to the pressure between the teeth of the gear and the pinion, would be too great at these speeds; therefore, the gears are made double so that half the load is taken by each wheel, the gear pressure on one side of the pinion balancing the pressure on the other side, thus eliminating the pressure in the pinion bearings.

The characteristic high velocities of the principal parts of the De Laval turbine also create some interesting practical problems.

We will first consider the turbine wheel itself, which is shown in section in Fig. 2. The wheel is designed with a factor of safety at normal speed of about 8, and with radial and tangential stresses due to the centrifugal force constant throughout the wheel. The profile of the wheel is a logarithmic curve asymptotic to the radial axis of symmetry of the wheel section. The buckets, which are inserted into milled slots in the rim of the wheel, when actuated by centrifugal force, load the solid wheel body at its outer periphery to an amount equal to the centrifugal stresses in the body. The stresses vary with the square of the speed, and with increasing speed they will gradually increase to a point where the wheel will burst.

In spite of speed regulating mechanism and safety stops, a motor of any kind might race, as all regulating devices are liable to derangement, and safety stops, which as a rule are seldom used, sometimes fail to operate. This, of course, applies also to steam turbines. It is therefore necessary to provide means for the prevention of serious damage. In the De Laval turbine this protection is obtained by reducing the thickness of the wheel close to the periphery, which naturally decreases the strength of the wheel at this point, the stresses here being about 50% higher than in the rest of the wheel. At normal speed the factor of safety at this point of the wheel is about 5; consequently the wheel will burst here at about double its normal speed, and in such a manner that the rim holding the buckets is broken up into pieces, which, on account of their small size, are unable to do any damage to the wheel case. At the moment the rim leaves the wheel, the stresses in the solid wheel body are considerably reduced, at the same time the wheel becomes unbalanced, and as the clearance between the heavy hub of the wheel and the safety bearings in the surrounding wheel casing is very small, the hub of the wheel will come in contact with the latter, which efficiently act as a brake on the wheel, and bring it to a stop in a short time, as with the buckets gone, the steam has no effect whatever on the wheel. Exhaustive experiments have verified these statements, it having been found that turbine wheels without this decrease in section at the outer periphery, having purposely been speeded up, would burst through the center in two or three heavy pieces, which, at the high velocity, a wheel case of ordinary proportions would not resist. Such pieces have been driven through an experimental wheel case of steel castings, having walls 2 ins. thick. With the wheels as made, however, they are perfectly safe, and in the event of the rim being stripped, no damage will result except to the wheel itself.

As it is possible to design a turbine wheel for any radial and tangential stresses, it might be asked why the wheels are not made so strong that it will be impossible, with the available steam velocities, to run them up to the bursting point. The reply to this is, that it would be too expensive and not practicable to design the rest of the turbine and connected machinery to run safely at a corresponding speed.

In this connection we may consider the speed regulation mechanism of the De Laval turbines. This consists of a common centrifugal governor, actuating a throttle valve in the steam supply line of the turbine. With this the pressure can be closely controlled, but not entirely shut off. In most cases, though, sufficient to prevent the turbine going above its normal speed when running light. This is especially true of turbines running non-condensing. In condensing turbines operating with very high vacuum, the passive resistances are sometimes extremely small, and even if the governor valve throttles the steam considerably below the atmospheric pressure, the remaining pressure may be sufficient, at no load, to increase the

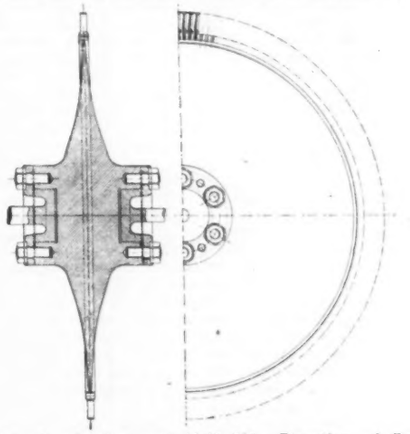


Fig. 2. Section and Half Side Elevation of De Laval Steam Turbine Wheel.

speed above the normal. To prevent this speed increase, a second regulating mechanism is provided, the purpose of which is to decrease the vacuum in the wheel case. This apparatus consists of a small valve which is directly actuated by the governor, but only after the governor valve in the steam line has been shut off. This valve either lets air into the wheel case, decreasing the vacuum, or in cases where the vacuum in the condenser must be maintained for other machines, it admits air into a regulating valve mechanism placed in the exhaust line of the turbine. When air is let into this valve, it more or less shuts off the communication between the wheel case and the condenser, thereby raising the pressure in the wheel case, which then increases the passive resistances of the wheel and checks the expansion of the steam in the nozzles, and, together with the steam throttle valve, holds the speed within the normal limits. In case of accident to the governor valve mechanism this air valve will also effectually prevent destructive racing.

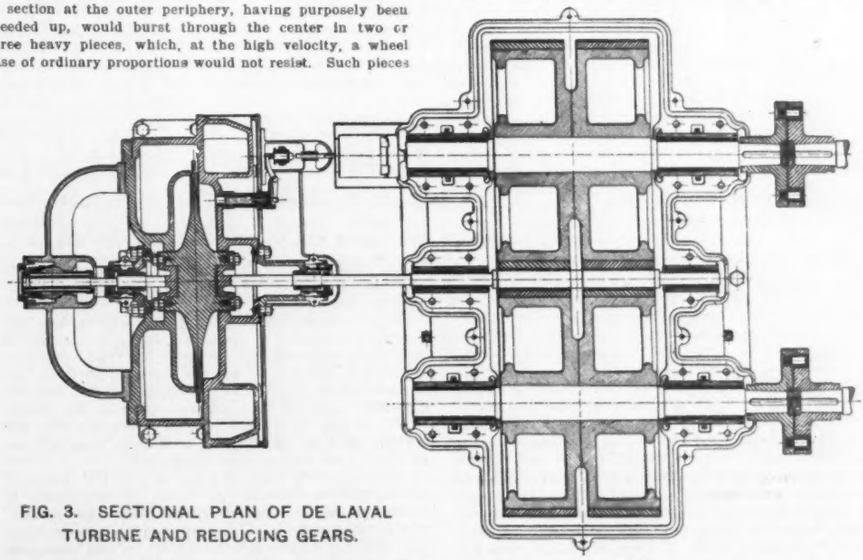


FIG. 3. SECTIONAL PLAN OF DE LAVAL TURBINE AND REDUCING GEARS.

The periphery velocity of the gear wheels is about 100 ft. per second. The pinion is made of high-grade high-carbon crucible or nickel steel. The gear wheels are made of soft steel of low carbon. The teeth are carefully generated at an angle with the shaft center and the pitch is very small, insuring a smooth contact with a minimum amount of noise. The noise cannot be entirely eliminated, but with great care in cutting the teeth, and giving close attention to alinement and center distances, it has been possible to reduce it to a minimum and to a point where it is in most cases of no consequence. The gears are con-

*A paper presented at the Chicago meeting of the American Society of Mechanical Engineers.

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tinually lubricated, but with a very small amount of oil. If they get the proper amount of lubrication and care is taken that no sharp grit, such as cement dust, coal dust, or the like, is allowed to enter them, they will operate for many years without visible wear. The gears are encased as much as possible, to prevent the entrance of dust or foreign matter. The gear wheels were originally made of bronze, but it soon developed that this material, as a rule, became crystallized after about two years of continuous operation, when pieces of the teeth were broken off and destroyed the gears. Steel gears have now been in operation for about nine years, without showing any of the disadvantages of bronze.

Little is to be said about the bearings. They are all lined with white metal. The low-speed bearings for the gear shafts are similar to bearings for electrical machinery of same speed, and are provided with ring oilers. Ring oiling, on the other hand, has not proven to be satisfactory for the high speed bearings. The turbine wheel shaft usually vibrates slightly, which is communicated to the oil rings, they then refuse to follow the shaft, and consequently do not furnish proper lubrication. It is also found that the temperature of the oil in this case will increase too much, and drip lubrication has been found more satisfactory, only a small quantity of oil being required. With the high speed it is very important that the lubrication should not be interrupted, as it takes but a short time for the bearing to run hot. Wick lubrication has so far proven the most reliable. It must, however, be arranged so that the oil leaves the wick tube in drops, and with a sight glass below the tube through which the amount of feed can be ascertained. The oil is filtered by the wick, which insures clean oil in the bearing, and the oil will flow as long as any oil remains in the tank. With oil tanks of ample size there will not be much attendance required. It seems, though, in the present advanced stage, that opposition is sometimes met with in having this method of lubrication used. The common sight-feed lubricator with such a small number of drops as are required, has the disadvantage of a very small opening for the oil, so that a small amount of dirt will suddenly interrupt the lubrication. The bearing will then immediately heat. Any mechanical arrangement for forced lubrication is in itself more or less apt to get out of order. It is all right for slow-speed machinery, which, in case of interruption of the oiling, can run a considerable time on the oil already supplied, and until the trouble can be discovered and remedied; but it is more or less uncertain for high-speed apparatus.

It might be interesting to touch on the practical difficulties which the De Laval steam turbine, like any other radically new machine, was compelled to meet, after it had been put on the market. The turbine naturally had its troubles from defects due to faulty material and workmanship, but these have been remedied. There have been troubles with bearings becoming overheated. This was partly due to faulty workmanship, but in many cases it can be ascribed to the lubrication, either to failure in keeping the oil reservoir filled, or else to the side-feed lubricators, which in themselves might have caused trouble. As more machines have been put on the market, they have become more fully understood, and are therefore receiving better attention; consequently these troubles have been gradually reduced. Furthermore, there has been trouble with the buckets. It has sometimes happened that one or more buckets have broken, and come out of the turbine wheel, but without doing any further damage. Generally the turbine, after losing a bucket, can be continued in operation, as the turbine shaft is sufficiently flexible to take care of the unbalancing, though it is best to take out the turbine wheel and replace the buckets. The only explanation of these troubles is that the buckets are subjected to vibratory strains of more or less unknown origin, as their ability to withstand centrifugal force and the action of the steam jet is amply sufficient. In the smaller sizes, below 100 HP., broken buckets have been very rare. In the larger sizes, it has been somewhat more frequent. Although the causes of bucket breakage are not yet accurately determined, it has been possible to remedy the trouble where it has occurred. One cause of the undue vibrations of the buckets may have its source in the turbine wheel itself, which, if not homogeneous, will, under action of the centrifugal force, expand unevenly in different directions, thereby unbalancing and causing vibration of the wheel at full speed. This trouble has been overcome by replacing the wheel. The buckets are also subject to more or less wear due to the action of the steam. The cause of this is also very difficult to determine. It may be that the buckets are chemically affected and that thin films of oxide are blown away by the steam, or it may be caused by mechanical wear due to small solid particles coming with the steam, such as rust, or scale from the pipes. It may also be due to some electrical phenomena. However this may be, it is a fact that wear takes place, and it is very doubtful that it can be entirely prevented. It has been found in a few cases that buckets have been worn out in a year, necessitating replacement. In other cases the wear has been very slight, even after a run of four to five years. The wear affects only the steam inlet side of the buckets, and will only increase the steam consumption to a slight degree. In tests made on a turbine of 100 HP., where the edge of the buckets had been worn away about $^1/_{16}$-in., the steam consumption was about 5% higher than with new buckets. The wheel and buckets are, however, so designed that an insertion of a new set of buckets can be easily made at a small cost.

In looking about for proper fields of usefulness, the De Laval steam turbine, in common with other steam turbines, first developed the direct connected electrical unit, no difficulty being met in adapting both direct and alternating current generators for direct connection to the gear shafts at their moderate speeds. In many cases De Laval Turbines can also be used, with advantage, for belt transmission.

However, the field where the De Laval turbine is particularly suitable is in connection with centrifugal pumps; these pumps require certain determined velocities to enable them, at a given lift and water quantity, to give the best efficiency. With the De Laval turbine it is easy to produce the most suitable velocities; with the small turbines, having one gear shaft, for all lifts from 15 ft. to 150 ft., and with the large turbines, with two gear shafts, for lifts from 40 ft. to 300 ft. These velocities are often difficult to obtain with other steam motors.

For a greater lift the centrifugal pump has been direct connected to the high-speed turbine shaft. The pump wheel will then revolve with a velocity of 10,000 to 30,000 revolutions per minute, depending on the different sizes. The pump wheel will naturally be very small, and will not produce any suction, but must be fed with another pump, which is connected to the gear shaft, running at a considerably reduced velocity. This latter pump sucks the water and presses it into the high-speed pump wheel, which then gives the high pressure required. Pumps of this type have been made for lifts up to a normal head of 850 ft. on a single wheel, which, at a decreased water quantity, can go up to 1,000 ft., the small pump wheel giving an efficiency of about 64%. They have in some cases been made, and are in operation, as boiler feed pumps.

Another field where the De Laval turbine is well-adapted is for direct connection to blowers for all pressures above 4 ins. water, for which a blower can be practically built. The high velocity of the turbine being particularly suitable for this purpose.

About the steam consumption, it is difficult to make any general statements. It varies for the same size turbine with the steam conditions, in about the same manner as for other steam motors, but the degree of variation can be considerably different for the various sizes of turbines, dependent upon the diameter and speed of the turbine wheel. It may be sufficient to give here a few diagrams showing the steam consumption of different sized turbines under more or less favorable conditions.

Fig. 4 shows the result of a test of a 10-KW. non-condensing turbine dynamo. The boiler steam pressure is 140 lbs. per sq. in.; steam, dry, saturated. The curves I, II, III, IV give the steam consumption per kilowatt-hour with all steam nozzles open during the varying conditions of the load, the governor valve alone having to take care of this variation by throttling the steam pressure. The curve IV shows the steam consumption with the nozzles shut off in proportion to the varying load. In this manner the nozzle will be supplied with steam of the full steam pressure at all times.

Fig. 5 shows a test made on a 30 HP. steam turbine motor, condensing, with 25½ ins. vacuum, steam pressure being 125½ lbs. per sq. in. above the governor valve. Steam, dry, saturated. The four different curves show how the steam consumption per brake horse-power varies with the varying load, with and without regulating the number of nozzles opened.

Fig 6. shows a test made on a 30-HP. steam turbine motor, non-condensing, with different steam pressure above the governor valve, with the nozzles [illegible] for the different steam pressure. The curves [illegible] respectively .35, 50, 75 and 100 lbs. boiler steam pressure per sq. in. The number of nozzles opened [illegible] been varied according to the varying load.

Fig. 7 shows the result of a test made on a 300-HP. steam turbine, steam pressure about 200 lbs. per sq. in., vacuum about 27 ins. The curve I, II gives the steam consumption for dry saturated steam. The curve III, IV gives the consumption for superheated steam. The superheat varied from 90° F. at maximum load to about 20° F. at the smaller loads.

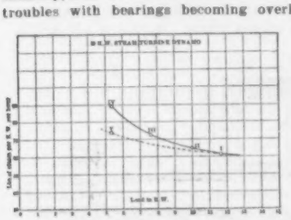


Fig. 4. 10-KW. Non-Condensing Turbine Generator.

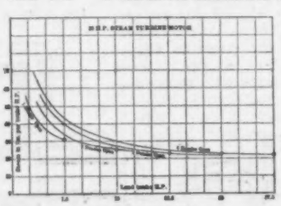


Fig. 5. 30-HP. Condensing Turbine.

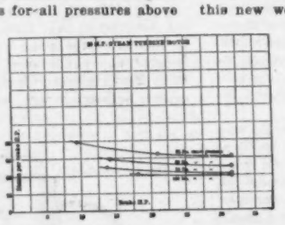


Fig. 6. 30-HP. Non-Condensing Turbine.

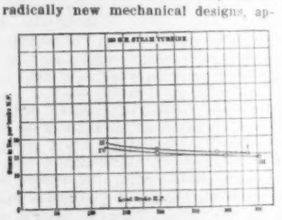


Fig. 7. 300-HP. Condensing Turbine.

CURVES OF STEAM ECONOMY OF DE LAVAL STEAM TURBINES.

THE STEAM TURBINE IN MODERN ENGINEERING.*

By W. L. R. Emmet,† M. Am. Soc. M. E.

The Curtis steam turbine, which has very recently appeared on the market, is the first radically new commercial machine different in type from either the Parsons or De Laval machines. The general purpose of the Curtis design is to produce results with a reasonable number of simple parts and at moderate speeds, while the Parsons turbine requires a very large number of small parts, and the De Laval turbine employs excessively high speeds inapplicable to mechanical purposes without the use of speed reducing gearing.

Mr. Curtis's experiment on steam turbines had been going on for about four years before the General Electric Co. undertook to build any machines for service. At the end of that period, and at a time now about four years ago, the author first became connected with the enterprise, being asked to express an opinion concerning the value of the invention. Other engineers had reported unfavorably, and the discontinuance of work was a possibility. The opinion given was that the invention afforded great possibilities, particularly in the matter of simplicity and economy of production; that the development of commercial machines was justified by the experiments and should be begun at once, and that the development of high degrees of steam economy was to be expected with further experience.

This report led to the beginning of work on a larger scale; the first step being to build a 600-KW. unit, which was put into operation at Schenectady in November, 1901. This machine was built on the general lines previously considered by Mr. Curtis, with a horizontal shaft and two stages with groups of wheels in separate casings. Tests of the machine, which were carried on for some months showed very good results. The success of this machine led to the undertaking of commercial work on a large scale, and the experience so far obtained and a careful study of mechanical possibilities led to the adoption for this new work of radically new mechanical designs, applied to bucket and nozzle arrangements similar to those previously used and first recommended by Mr. Curtis. The first machines designed of this new type were a 5,000-KW. unit for the Chicago Edison Co. and a 500-KW. unit, the first of which was installed at Newport, R. I. Four machines from the former and about forty from the latter design have up to the present time been installed.

These machines are built with shafts in a vertical position; the total weight of revolving part being borne by a step-bearing at the foot of shaft, and shaft being steadied and alined by three bearings, one at the top of generator, another near the foot of shaft, and a third between the generator and turbine. Many reasons led to the adoption of this arrangement which involved some untried features, but which afforded very great practical advantages. A careful consideration of designs indicated that the untried features involved little risk of serious difficulty, and experience has shown that this judgment was sound. Some of the important advantages of the vertical shaft type are as follows:

The relative positions of revolving and stationary parts are definitely fixed by the step-bearing. The stationary part is symmetrical, easily machined and free from distortions by heat. The shaft bearings are relieved from all strain, and friction is practically eliminated. The shaft is free from deflection and can be made of any size with-

*From a paper presented at the Chicago meeting of the American Society of Mechanical Engineers.

†Engineer Lighting Department, General Electric Co., Schenectady, N. Y.

out reference to bearings, which can be placed where convenient and operated with surface speeds which would not be practicable with the horizontal arrangement. These features make possible the use of a very short shaft, and consequently the longitudinal spacing of moving and stationary parts is very little affected by temperature differences. The turbine structure affords support and foundation for the generator. The cost of foundations is very small, and the solidity and alinement of foundation is not of vital importance. Much floor space is saved. All parts of the machine are conveniently accessible. Failure of lubrication cannot injure the shaft or other expensive parts.

Another new feature of these designs is the arrangement of valves; the turbine being governed by the successive opening of steam operated valves, which are independent of each other, but which are all controlled by the centrifugal governor. With this arrangement the speed control of the turbine is not dependent upon the successful operation of all the valves, since the governor automatically keeps open as many valves as the machine requires, and in the event of trouble with one valve opens another to take its place.

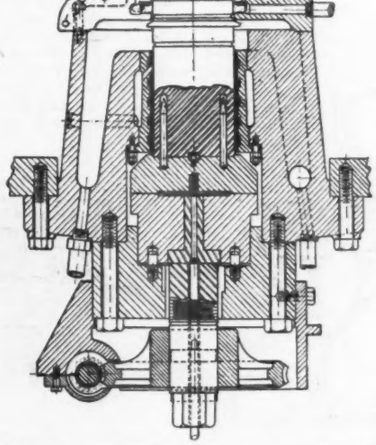
In this first Chicago machine there are two stages, each stage having a single wheel which carries four rows of moving buckets. On the stationary part there are three rows of stationary buckets opposite each group of nozzles used. The shaft is in one piece from the step-bearing to the top of the generator. The wheels are of cast-steel mounted upon it with taper fits. The stages are separated by a cast-iron diaphragm which is fitted with valves which are now operated by hand, but which are being arranged to operate automatically; it being advantageous to constantly maintain a certain pressure relation between the stages.

The step-bearing is shown in the accompanying cut and consists of two cast-iron blocks, one carried by the end of the shaft and the other held firmly in a horizontal position and so arranged that it can be adjusted up and down by a powerful screw. The lower block is recessed to about half its diameter, and into this recess oil is forced with sufficient pressure to balance the weight of the whole revolving element. The amount of oil required is small. About 5 gallons per minute is used in the 5,000 KW. machine, but with a good alinement it could be satisfactorily operated with a much less amount. The oil after passing between the blocks of the step-bearing wells upward and lubricates a bearing supported by the same casting. This whole structure is inside of the base, and a packing is used between the oil chamber and the base, so that oil or air cannot get into the vacuum chamber. A small steam pressure is maintained between the sections of this packing, in order that these objects may be accomplished with certainty. In many cases these same step-bearings have been operated with water instead of oil, in which case no packing is necessary; the water being allowed to pass into the base. In some of our latest designs water will be used exclusively; the lower surface of step-bearing being of wood and no packing being provided.

The extreme conditions to which these step-bearings are subjected, and a complete lack of precedent for such designs led at first to many doubts concerning the success of this feature. Experience has, however, shown that these doubts were without foundation. Practically no troubles or interruptions have resulted from this cause, and the step-bearings have shown a ruggedness and stability far beyond our expectations. Many of our turbines have been operated under more or less temporary conditions in incompleted stations, and there have been many accidental stoppages of step-bearing pressure while machines were running. In hardly any cases have such stoppages caused even an interruption of service. The step-bearing surface cuts immediately when lubrication is stopped, but the metal from it is removed very slowly and it has the power of re-establishing itself almost immediately when oil flow is again started. We expected that this condition would exist in smaller machines, but did not hope for it in larger machines, and took precautions to provide accumulators and other auxiliaries necessary for permanent maintenance of step-bearing pressure. In spite of these fears and precautions the step-bearing pressure has through accidents failed five or six times in the Chicago Edison plant, and all of the three machines now operating there are running on step-bearings which have been subjected to such stoppages. In no case has any harm resulted to the machines, and the bearings have always operated just as well as if they were in a perfectly new condition. Our policy in adopting the vertical design and putting our dependence in the step-bearing was to put all our eggs in one basket and watch the basket. We have now discovered that very little watching is necessary. In our newer designs we are providing a powerful brake bearing on the lower surface of a chilled iron ring carried by the lower wheel. This brake can be conveniently operated from the outside, and can be used to take the whole weight of the revolving part in case the step-bearing support should fail. In ordinary operation the shoes of this brake will be set about 0.01-in. below the brake ring. It is thus in a position to receive the revolving part in case the step-bearing support should fail. Another and more important function of this brake is to stop the machine when it is desired to do so. One of the 5,000 KW. vertical shaft machines will run for four or five hours after steam has been shut off, unless load is put upon it or a brake is applied.

One of the most important matters in all steam turbine work is the matter of balance, and the importance of good balance applies as well to vertical turbines as those that are operated in a horizontal position. When the balance is good the bearings on vertical turbine shaft are practically free from strain or friction. It is possible to operate these machines successfully with very considerable imperfection balance, but a perfect balance is practicable, and should be attained in every case.

The 5,000-KW. and 500-KW. two-stage machines above mentioned are, as I have said, designed in accordance with Mr. Curtis's original conceptions before we had the benefit of much study and practical experience. After construction of these machines had been begun, we became convinced that other arrangements of steam parts would be more advantageous, and began the design of a new type, the construction of which was well advanced before our first experiences with the first type were obtained. Theory and experiment indicated that we could obtain better economy from the new design adopted, and it also affords the advantages of greater simplicity and a better mechanical structure. These new machines are ideally simple, with large clearances and practically no tendency to distortion. No parts of them are subjected to heavy strains, and no particular accuracy or thoroughness of workmanship is required in any part. Machines of this



Section of Step-Bearing of Curtis Steam Turbine.

type, which have very recently been put into operation, have started without any trouble or interruption and given very perfect service.

After we had embarked upon the manufacture of a great number of large turbines, and had already put into production this new type, we began to receive reports of rapid advances in the turbine art elsewhere. Large turbines of the Parsons type in Europe produced high steam economies, and we began to meet in competition good guarantees of steam economy with relatively low prices. The results of tests on our first machines were, therefore, awaited with great interest. We had good reasons for our beliefs concerning the results which could be produced, but we were very slightly supported by practical experience, and were dealing with a problem which involved immense values.

There have been many delays in completing the first of these new machines, and it has been necessary to interrupt tests in order to meet customers' requirements, and mistakes and accidents in steam plant have caused further delay in testing. We have recently obtained accurate tests from this first new machine as originally designed. The capacity of this machine is 2,000 KW. It operates a 6,600-volt 25-cycle generator at a speed of 750 revolutions per minute. It is temporarily installed in the General Electric Co.'s power station at Schenectady, with a surface condenser having 6,000 sq. ft. of cooling surface. The following are results obtained under different running conditions. The tests on March 12 and on May 11 were made upon different machines of similar design. Considering the different conditions, the results are consistent.

	March 12			May 11
Load in kilowatts	637	1,000	2,000	2,270
R. P. M.	750	750	750	750
Gage pressure	150	160	155	160
Superheat F.	215	242	242	250
Corrected vacuum	28.2	28.9	28.73	28.1
Lbs. steam used, KW.-hr.	20.1	16.3	15.3	16.2

Such analysis of results as we have been able to make indicates that a different proportioning of certain parts will give us a substantial improvement.

SOME THEORETICAL AND PRACTICAL CONSIDERATIONS IN STEAM TURBINE WORK.*

By Francis Hodgkinson, M. Am. Soc. M. E.†

An ideal elementary turbine may be said to consist of a steam nozzle directing a tangential jet of fluid upon a bucket wheel of the Pelton type. This type of bucket is selected because it may be capable of giving a complete reversal to the jet, so that the spent fluid may issue from buckets without any velocity. Even this type may not be quite ideal because of the distance which must necessarily exist between the outlet of the nozzle and the receiving wedge of the buckets, the effect of which will be to cause friction between the jet and the surrounding medium, causing eddies, and perhaps entraining some of this surrounding medium.

Steam expands approximately adiabatically in the nozzle, and on its arrival at the exit should be thoroughly expanded to the exhaust pressure, so that its heat energy may be entirely transformed into kinetic energy, and its velocity be the greatest attainable on striking the buckets. For conditions of maximum efficiency, the same relation between velocities of jet and vane applies to the steam impulse wheel, as to its hydraulic analogue; viz., bucket speed equals one-half of jet speed.

The difficulty of such a design as this is obviously due to the fact that the velocity of steam expanding between even moderate differences of pressure, is so high as to render the most efficient velocity of the bucket difficult to provide for because of the limitations of strength of materials. Thus, for terminal pressure of 165 lbs. and 1 lb. respectively, the bucket speed should be 2,025 ft. per second. In practice the maximum attained is 1,378 ft. per second in a 300 HP. De Laval turbine, which is 32% below speed. In a 50 HP. turbine, the bucket velocity is 58% below normal, but even at this speed, the radial stresses amount to 23,000 lbs. per sq. in.

THE EXPANSION OF STEAM.

The so-called phenomenon of maximum flow of steam through an orifice is now generally understood. It has been generally stated that the velocity of steam flowing through an orifice will not exceed about 1,500 ft. per second, no matter what the differences of pressure may be. This condition has been said to be reached when the exhaust pressure bears a certain ratio to the initial pressure. This ratio has been variously given from 52% to 58%.

Experiments made at East Pittsburg, however, seem to show that the above figures vary with the initial pressure. The velocity becomes higher and the above ratio lower with the lower initial pressure. Therefore, in the above-mentioned elementary turbine, if the initial pressure is 150 lbs. per sq. in., and the exhaust pressure is greater than 85 lbs. (57% of the initial pressure), all that is needed in the shape of a nozzle is a well-rounded orifice. If the exhaust pressure is less than 85 lbs. a divergent nozzle, as used by Gustav De Laval, is necessary. Without this divergence, the steam will expand outside of the nozzle where it is uncontrolled by its walls, and consequently much of the expansion will take place laterally, which will not further accelerate the jet.

A further reason for the divergence is apparent from the fact that the work done by the expanding steam varies nearly in direct proportion to the number of expansions, and also varies directly as the square of the velocity. The volume of the steam, therefore, increases much more rapidly than the velocity, and room must be provided for its proper expansion in the nozzle.

A theoretical design of a divergent nozzle is shown in Fig. 1, which considers a nozzle expanding 1 lb. of dry saturated steam per second from an absolute pressure of 165 lbs. per sq. in. to 1 lb. per sq. in. It has been assumed that the expansion will be adiabatic, and that equal increments of work will be performed in equal increments of nozzle length.

The abscissae are laid out to uniform scale and represent the foot-pounds of energy given up by the steam expanding between the limits of pressure referred to the scales of ordinates. The curve of pressure shows the pressure drop corresponding to increasing work. The velocity curve is calculated upon the assumption that all energy of the expanding steam has been expended internally and converted into velocity. The curve of the areas of the nozzle is found by the equation $a = \frac{s \times x_2}{V}$ in which a = area of nozzle, s = specific volume, x_2 = quality of steam, V = velocity of steam.

An examination of the curve shows that the throat of the nozzle corresponds to a velocity of 1,500 ft. per second and to a pressure 57½% of the initial pressure.

It is logical to assume that steam expands adiabatically in a nozzle, as nozzles are generally small relative to the amount of steam passing, so that there is little opportunity for any interchange of heat. The state of the steam at the outlet of nozzle, therefore, is, except for some frictional losses, the state of the exhaust of an ideal engine. It contains considerable water which has been condensed during the adiabatic expansion of the steam. This may amount to over 20% in cases of low exhaust pressure, and

*Extract from a paper presented at the Chicago meeting of the American Society of Mechanical Engineers.

†Westinghouse Machine Co., East Pittsburg, Pa.

is discharged from the nozzle in the form of vapor of fine spray.

If the steam issuing from this nozzle be brought back to rest in a closed chamber, the kinetic energy of the jet will be reconverted into heat, and the expanded steam will become superheated, just as in the well-known throttling calorimeter.

An interesting fact on this subject was pointed out by Prof. W. H. Watkinson, of England, (Transactions of the Institute of Engineers and Shipbuilders in Scotland, vol. xlvi., Part V.), who shows that if, after the energy of the jet has been converted into velocity, we were to separate therefrom the water of condensation and then bring the jet to rest, the steam would become highly superheated.

This method might be utilized for obtaining superheated steam at a moderate pressure, if any practicable method could be devised for separating the water of condensation from the jet before it is brought to rest. For instance, operate the boiler at 400 or 500 lbs. pressure and expand in the manner above outlined to 150 lbs. per sq. in., then separating the moisture and bringing the steam to rest, superheat would be obtained. An analysis of the cycle will show this method to have about the same efficiency as though the steam were generated in the boiler at 150 lbs. and afterwards superheated to a corresponding degree.

CAUSES OF DEPARTURE FROM THE IDEAL.

It is probable that the state of steam issuing from a good-sized nozzle does not deviate much from the ideal. The only losses will be due to the friction and conduction of heat along the walls. The larger the nozzle, the less will be the ratio of perimeter to cross section, and consequently the less these losses will become. In the ideal turbine above mentioned, if the form and the velocity of the buckets were such that they might wholly absorb the velocity of the jet without friction, the state of the steam on leaving the buckets would be the same as when it left the nozzle, and we would have a turbine approximating an ideal engine, except for the frictional losses of the nozzle.

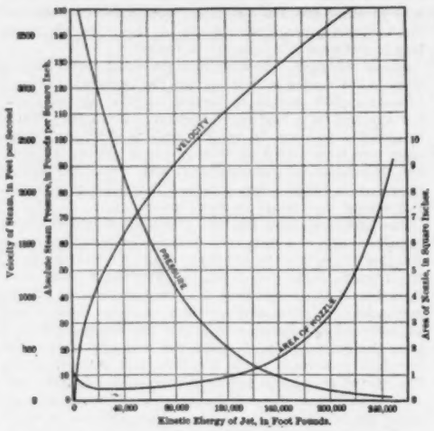


Fig. 1. Diagram Illustrating Theoretical Design of Nozzle to Expand Adiabatically 1 Lb. per Second of Dry and Saturated Steam from 165 Lbs. Absolute Pressure to 1 Lb. Absolute Pressure, Assuming that Equal Increments of Work Will be Performed in Equal Increments of Length of Nozzle.

In practice, the kinetic energy cannot be wholly absorbed, the buckets cannot generally be arranged to satisfactorily make a complete reversal without attendant disadvantages; hence the steam issues from the bucket with residual velocity. Where the jet is arranged to impinge upon the bucket wheel tangentially or at the sides, a departure from the ideal occurs. In the De Laval type, complete reversal cannot be obtained, as the spent steam must clear the buckets; in the Pelton type, the angular position of the bucket with reference to the jet is continually changing, resulting in distortion of the jet from its ideal path. There is also in some forms a spill from the buckets, and always frictional losses and eddies, which have the effect of lowering the velocity and heating up the steam similar to, but to a less extent than the effect in a throttling calorimeter.

With high steam velocities, the skin friction of the fluid passing over surfaces such as buckets amounts to a considerable loss, though the exact amount of such losses is unknown. Professor Perry says:*

> Friction in fluids is proportional to the speed when the speed is small; to the square of the speed when the speed is greater; and at still greater speeds, the friction increases more rapidly than the square of the speed. The resistance to motion of a rifle bullet is proportional to the square root of the fifth power of the speed.

In the type of turbine above described, the velocity of the steam is approximately twice that of a rifle bullet.

Dr. Stodola, in his excellent work, "Die Damp Turbine," quotes a test by Lewici upon the friction of a 30 HP. De Laval disk in air and vacuum. The turbine was driven by a calibrated motor, and in order to bring it up to speed, the following power was required:

	Resistance.	
	Atmosphere. Per cent.	19.6-in. vacuum. Per cent.
Dry saturated steam, 3.3 HP. =	11	5
Superheat 300° C.	6.25	2

*"Applied Mechanics," by Prof. John Perry, p. 79.

In view of these facts, it would seem desirable to avoid high steam velocities as much as possible, because of the resulting frictional losses. Another reason is the erosive action of the steam with high velocities. This is quite serious when the steam is initially wet, due to foaming boilers. In this case, matters are generally made worse by the moisture generally carrying with it various kinds of solid impurities.

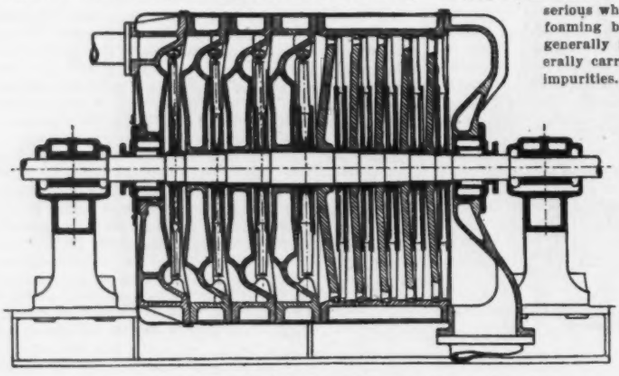


FIG. 2. CROSS-SECTION OF ZOELLY STEAM TURBINE.

In this connection, the author lately had some hard drawn Delta metal blades exposed to two steam jets, the one issue from a diverging nozzle with 150 lbs. boiler pressure behind it, and the other from a rounded orifice with 1 lb. pressure. The size of the outlet of the two nozzles is the same in each case, and the respective velocities were approximately 2,000 and 600 ft. per second. The blades were kept continuously exposed to the jets for 128 hours, and a considerable amount of erosion was observed on the blades subjected to the higher velocity. A rather curious feature is that the erosion was maximum at the center and the extreme edges of the jet. No attempt was made to observe the quality of the steam; the nozzles were merely connected to a steam pipe in the works.

TYPES OF TURBINES.

The ideal turbine that has been above referred to is essentially a refined form of that built by Branca, in 1629. The present De Laval turbine may be said to be of a like type, in so far that its elements consist of one single bucket wheel and one set of expanding nozzles.

THE STUMPF.—A more recently developed turbine, the Stumpf, likewise utilizes these distinguishing elements of the simple impulse turbine, with, however, a slight departure from the De Laval arrangement in the use of tangential nozzles with buckets of the Pelton form milled in the periphery of the wheel. These are slightly pitched from the shaft in order to provide metal for succeeding buckets. A characteristic of this form of turbine is the large wheel diameter employed, and it is in this direction that low shaft speeds are secured. For example, a 500 HP. turbine with two disks 5 ft. in diameter has been constructed and run at a speed of 3,000 revolutions per minute with a rigid shaft. In later forms of the Stumpf turbine, it has been sought to utilize a residual velocity of the steam leaving the buckets by redirecting around a circular guide, so as to impigne again upon another set of buckets, milled in the periphery of the wheel alongside the other row. The steam jet, after leaving the nozzle, is, therefore, reversed 180° twice before finally leaving the wheel. It is evident, however, that this arrangement is subject to the same disadvantage as regards fluid friction, as the simple impact arrangement.

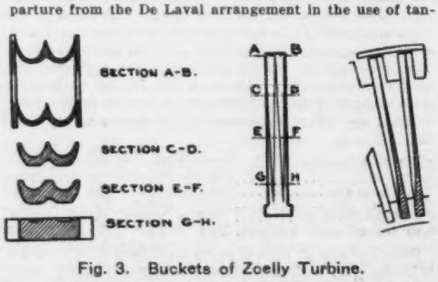


Fig. 3. Buckets of Zoelly Turbine.

COMPOUND SYSTEMS.—On account of the difficulties of construction, and losses attendant upon the use of high steam velocities, various methods of compounding have been proposed, the objective point of the compounding arrangement being a subdivision of total velocity among several stages, so that the working velocities in any one stage might be reduced to a more practicable degree. The effect of compounding does not, however, reduce the stage velocities as promptly as might be at first thought, for the reason that the velocity varies as the square root of the energy of the steam. Thus, if the simple impact turbine were constructed with two stages instead of one, the stage velocity would be reduced from 4,012 ft. per second to 2,835 ft. per second, assuming a range of pressure from 165 lbs. to 1 lb. absolute. If it were constructed in four stages, the velocity would become 2,050 ft. per second, under the supposition that the entire velocity of the jet were abstracted in each stage. In order, therefore, to reduce the steam velocities to 500 ft. per second, about 64 stages would be required in the turbine.

THE CURTIS.—The nearest approach to this method of compounding the simple impact element is carried out in the Curtis turbine, in which two or more stages are employed to carry out the total range of expansion from boiler to condenser. Each stage comprises a set of expanding nozzles and a wheel carrying more than one row of buckets. The peripheral speed of the wheel is kept within convenient limits, so that if only one row of buckets were employed, the steam would issue from it with much residual velocity.

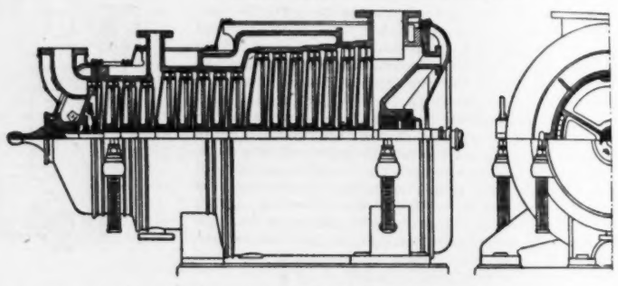


FIG. 4. RATEAU 25-STAGE TURBINE.

In order to abstract this as far as possible, a set of guides is interposed which redirects the steam leaving the first row of moving blades, into a second set. The velocity of the jet is thus reduced by each reversal in the moving blades, and this process is carried out as many times as may be necessary to absorb the initial velocity of the jet. Thus the steam in each stage is alternately accelerated in the nozzle and retarded in the blades. Low shaft velocities are secured by this arrangement, but this is largely due to the use of large diameters of wheel, and to the fact that, generally, a very small arc of all but the last wheel is being acted upon by the nozzles at one time. This construction makes desirable a fine axial clearance.

THE ZOELLY.—The idea of compounding has been applied in a slightly different manner in the Zoelly turbine, a cross section of which is shown in Fig. 2. One section of the turbine—the high pressure end—consists of several tangential impulse elements arranged in separate compartments. Each is fitted with a number of nozzles in which part of the expansion is carried out, and the velocity immediately abstracted in the buckets. In the later stages, however, a different construction is employed by reason of the increased volume of steam. The nozzles are here slotted in the wall of each compartment, and the steam flow is in the form of an annular jet, striking the bucket wheel in the manner of the De Laval turbine. To accommodate expansion, the radial widths of the nozzle parts are progressively increased to the end of the turbine. The principal features of the Zoelly turbine lies, however, in the construction of the disk wheel to accommodate extraordinarily high peripheral speeds. The buckets consist of metal strips about one-half the radius of the wheel length. They are secured to a two-piece hub by projections, as shown in Fig. 3, and a cross-section of approximately uniform strength is obtained by milling the

bucket curves deeper from hub to rim. Thus, the weight is largely decreased, as are also the internal stresses to be provided for. Zoelly found by experiments that his buckets might be spaced much farther apart than customary in the De Laval turbine, without serious loss in efficiency, which justifies his construction. The peripheries of the buckets wheels are surrounded by stationary metal shrouds to prevent radial escape of the steam. The sides of the buckets are further enclosed in sheet-steel housings to reduce the windings which would occur with exposed buckets of such length. Complete reversal of the steam jet is impossible, and the action is similar to that of the familiar Pelton wheel.

THE RATEAU.—Professor Rateau, in his later form of turbine, has discarded the simple impact element and employed the subdivided element to a still greater extent than any hereinbefore described. Fig. 4 shows a section of a Rateau turbine of 25 stages. Annular nozzles are provided in each division wall between stages. The stages being numerous, the pressure drops are small, such that the nozzles require no divergence. The increasing nozzle area is secured through increasing the arc, or percentage of total circumference, rather than the nozzle width, as in the Zoelly form. Thus in the later stages, a complete annular jet results, and the entire periphery of the wheel is made use of. This seems a decided step in the direction of reducing fluid velocities, but even this form is subject to frictional losses, due to large disk areas operating at high speeds in dense media.

PARSONS.—A still further method of securing the advantages of compounding is represented in the construction of the Parsons turbine, which, however, antedates, both in conception and introduction, other forms of modern steam turbines.

In the types previously described, the original impact element has been made use of in simple or compounded form, the pressure fall being secured by nozzles and the velocity abstracted by vanes. Thus each bucket wheel

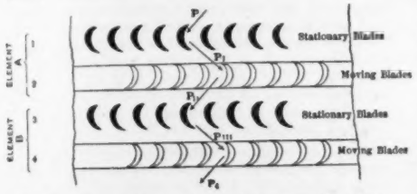


Fig. 5. Diagram of Blades of Parsons Turbine.

presumably rotates in an atmosphere of uniform pressure at all points. Mr. Parsons, however, early conceived the idea of so designing and locating the turbine vanes that they should perform the functions of bucket and nozzle as well, at the same time confining the steam to the periphery of the wheel in order to avoid superficial friction in large disk areas. The actual construction of this type of turbine is so well known as to require only passing comment here. The steam volume progressively increases from the inlet to the exhaust in the annular space between stator and rotor. The entire expansion, which is approximately adiabatic, is carried out within this annular compartment which essentially corresponds to a simple steam nozzle. There is this difference, however, that whereas in a nozzle the heat energy of the entering steam is expended upon itself in producing high velocities of efflux; in the Parsons turbine the total velocity, due to expansion, is subdivided into a number of steps, in each of which it is reduced through the dynamic relation of jet and vane, so that a comparatively low velocity is maintained from inlet to exhaust; this generally varying from 150 ft. per second as a minimum at the high pressure end to about 600 ft. per second as a maximum at the low-pressure end. The action of the steam in this turbine differs from other types also in this respect, that the steam expands in the ring (2) of moving blades (see Fig. 5), so that a reactive effect is produced in addition to the impulse of the steam, from (1). The total torque produced at the shaft from the ring (2) of moving blades is, therefore, due to impact of steam from (1) and reaction from (2). This process is repeated in each element of the turbine, and the average velocity may be maintained at a uniformly low figure throughout. It is evident that here frictional losses, due to high velocities of efflux, are largely reduced.

It has been often held that unless very high vacuum—in fact, an almost uncommercial one—be provided, the economy of the turbine will suffer. This may be so in certain types in which there are idle portions of the bucket wheels rotating in dense media. In the parallel-flow type, however, losses from this source are not so much in evidence, by reason of the fact that the steam is confined to the annulus, and the entire circumstance is active in producing torque, thus reducing the proportion of friction to useful work. Tests show that the results from turbines operating under poor vacua are not less excellent, relatively, than those obtained with high vacua.

The question is frequently asked why three diameters of barrel have been generally selected in the Westinghouse-Parsons turbine. This selection has no bearing whatsoever on the design of the machine, but is merely one of mechanical convenience. The proper expansion can be provided for just as well should there be one or several different diameters. It would be found, however, that if a speed and diameter of drum were selected that would permit convenient proportions of blades at the outlet, the blades at the inlet of the turbine would become unmechanically small; similarly, if diameters and speeds were selected to suit the inlet blades, the areas of the blades in the last stages would become unmanageably large. By varying the barrel diameters at several convenient points, corresponding variations may be made in the velocity of the steam, thus permitting blade designs of convenient proportions for both extremes.

It is an important feature of the parallel-flow turbine that the entire annulus between rotor and stator is filled with working steam. It permits the use of large axial clearances between moving and stationary blades without loss in efficiency. In actual practice, this is never less than ⅛-in., and in large blades it is as much as 1-in. In all forms of impulse turbine, separation of nozzle and vane results in surface friction of the jet, and particularly an entrainment of the surrounding medium, as in the fashion of a steam injector, thus increasing fluid friction by drawing the steam backwards through the idle portion of the wheel.

Although small axial clearances are unnecessary in the Parsons turbine, it is desirable to employ as small radial clearances as possible in order to prevent leakage of steam from stage to stage. In order to avoid over-estimating the probable extent of this leakage, it is necessary to bear in mind a point which is usually lost sight of, and which, in a considerable measure, offsets the loss from this source. In a machine of given size, the radial clearances between the ends of blades and the walls of the turbine would presumably be constant. The greater leakage would, therefore, naturally occur at the high-pressure end of the turbine, or at the beginning of the expansion. By the time the lower stages of the turbine have been reached the total volume of the steam has become so great, compared with the clearance area, that the latter becomes unimportant. All leakage steam returns energy to the working steam in the form of heat, as its action is similar to wire drawing in a restricted passage; hence it is superheated to a slight degree and serves to partially dry the working steam which contains considerable moisture, due to adiabatic expansion.

In any type of turbine it is necessary to provide glands at the ends of the casings to prevent the escape of steam or the influx of air into the turbine at the point of entry of the shaft. Air leakage is particularly detrimental in cases where it is desirable to maintain high vacuum. Various forms of packing glands have been used, but the later type Westinghouse-Parsons turbines are fitted with an arrangement of water-sealed glands. They require no lubrication, and it is impossible for any oil to escape from the bearings or the lubricating system into the steam spaces. There are no rubbing surfaces in these glands, and it is found that they do not wear out. The water used for sealing them is small in quantity, but it is not necessarily lost, as it may, in a power plant, be taken from the feed-pump delivery and the overflow returned to the feed-pump suction.

Steam enters the turbine through a steam strainer and thence through a poppet valve which is controlled by the governor. When in operation, this poppet valve is continually opening and closing at constant intervals, the periods of which are proportional to the speed of the turbine. At light loads, the valve opens for very short periods and remains closed during the greater part of the interval. As the load increases, the valve remains longer open, until finally continuous full pressure is obtained in the high-pressure end of the turbine. At this time the valve does not reach the seat at all, but is merely vibrating without sensibly reducing the pressure of steam in the turbine. This, in a turbine, would correspond to somewhat over full load.

On the load being still further increased, an auxiliary or "secondary" valve, begins to open and admits steam as may be required to a later stage in the turbine where the working steam areas are greater, thus increasing in proportion the total power of the turbine. The operation of this poppet valve is the same as the main admission, so that the governor automatically controls the power and speed of the turbine from no load to such overloads as are generally beyond the limits of generating apparatus built on normal ratings. The economy drops off slowly as the "secondary" valve opens, but, on the other hand, the range of load at which the turbine may be economically operated is greatly extended.

The intermittent admission of steam to the turbine is productive of some gain in economy at light loads by keeping the temperature range greater than would be possible if the steam were throttled. Another advantage to be derived from this method of admitting steam is that the admission valve and the mechanism that operates it are constantly reciprocating, and consequently get no opportunity to become stuck. The reciprocating motion necessary to operate the mechanism originates with an eccentric driven by the turbine, and is transmitted through the clutch of the governor, causing a continual disturbance; such that the governor is at all times ready to go to a new position with the least change of speed, simply because the "friction of rest" does not have to be overcome. On the larger size turbines, the governor is supplemented by a special automatic centrifugal safety stop which is mounted at the end of the shaft and which actuates, by means of high-pressure steam, an auxiliary self-closing throttle valve located in the main steam pipe supplying the turbine. The safety stop may be set at any predetermined speed, which, if attained, causes the turbine to be brought to rest. It is employed mainly as a precaution against damage due to any possible derangement of the governor mechanism.

With the form of governor employed, the speed regulation may be kept to within 2% between friction load and full load, or 1% either side of the mean speed. Full load or overloads may be entirely thrown on or off without causing more disturbance than a momentary surge of speed of about 4% or 5%.

A turbine has the important advantage over the reciprocating engine; that local temperature conditions vary but little during operation and on steady load are absolutely constant. The reversals of temperature in a reciprocating engine cylinder have no equivalent. Thus the temperature of rotor and stator is at all points approximately equal to that of the steam in the corresponding expansion stages. Generally the stator is made of cast iron and the rotor of steel, so that the differential expansion that must necessarily exist between them has the effect of increasing or decreasing the axial clearances between running blades at different loads. This, however, is unimportant with this type of turbine because of the ample axial clearances provided. The exhaust end of the turbine is bolted to the bedplate, while the steam end is provided with a sliding foot working between machined ways on the bedplate, so as to permit the turbine to expand, as it will. In types of turbines, however, where small axial clearances exist, this question of differential expansion is not such a simple matter.

It has been advanced that the blade construction employed in the Parsons turbine constitutes an element of complexity, which also is not conducive to low cost of construction. The author is, perhaps, not conveying new information in stating that the blades are rolled out from special bronze or steel into long strips, then sawed into the proper length, and finally mounted around the periphery of the rotor and the stator in grooves with special separating pieces, the whole being finally caulked in position. In practice, it is found that with this construction the blades are never released, except through some special cause, and the construction is of immense advantage in minimizing the delays due to accidents.* By placing the shaft in a sling, the rotor can be lifted out by a crane and the entire interior examined. Such a turbine can be taken apart and completely reassembled inside of two hours, which cannot be said of many types of prime movers now known to us.

In view of the widespread discussion upon the merits of a reheater in reciprocating engine work, it may be of interest to mention the results of its application to steam turbines. The earlier Westinghouse-Parsons turbines of large size were constructed in tandem two-cylinder form for the purpose, not only of reducing the span between bearings, but also to permit the introduction of a receiver between high-pressure and low-pressure cylinders, the arrangement being intended to separate as much moisture as possible resulting from adiabatic expansion, and to superheat the remaining steam. Exhaustive tests have, however, shown the reheater to be of little, if any, value in increasing the economy of turbine when the high-pressure steam condensed in the reheater coils was charged up against the turbine. An improvement in the separator resulted in an improvement in the operation of the reheater, but, notwithstanding this, no advantage due to the reheater could be observed, and its application does not seem warranted, on account of the decreased compactness of the machine.

In the course of regular operation of power stations, it is not an unusual occurrence that wet steam comes over from the boilers, due to foaming, overfilling, or other causes. The effects upon reciprocating engine machinery need not be commented upon here. In several instances of turbine plants, slugs of water coming over from the boilers have been known to bring the turbine almost to a standstill, but without any apparent damage resulting. As soon as the water passes over to the condenser, the turbine again regains its speed. The effect on the economy of entrained moisture in the steam has been found to increase the steam consumption to an amount about twice the percentage of moisture in the steam, i. e., 2% of moisture will decrease the economy about 4%.

Finally may be mentioned the system of lubrication de-

*Such accidents are, however, of rare occurrence, and one that may be attributed to the blading construction has yet to happen. On one occasion an expanding exhaust pipe, which had been too firmly anchored at the lower end, occasioned sufficient distortion of the turbine casing to destroy several rows of blades. The turbine was immediately shut down, the casing opened and the debris removed. It was then again put under steam and continued in full load service during the day without further trouble or apparent effect on its capacity. At night, after extra blading had arrived from the factory, the machine was again opened and the damaged rows replaced. The repairs were made during several short stoppages at nights, but the turbine was kept in uninterrupted daily operation. The accident only kept the turbine out of service about three hours.

sirable with turbine outfits. Essentially a point in mechanical design and independent of the steam cycle, it is nevertheless one on which the successful operation of any machine is absolutely dependent. Although possessing extraordinary features of excellence in the matter of securing great compactness of design, forced lubrication, as ordinarily understood to mean—oil under high pressure—does not seem entirely desirable. In the Parsons type of turbine, the projected areas of the journals are proportioned so that the entire weight of the rotating element may be supported upon a fluid film of oil through capillary action alone. A small pump, driven from a worm gear upon the shaft, circulates oil through a closed system, comprising in the order of their arrangement: pump, oil cooler, bearings, and reservoir. The oil is always applied to the bearings at the point of least pressure; that is, it enters at one end and follows a groove along the top of the shell, from which it is distributed around the shaft. The pressure impressed upon the fluid films is due simply to a static head of 1 to 3 ft., sufficient to insure thorough flushing of the bearings. It is probable that the shaft never comes into actual contact with the bearings, but is separated by the oil film. This is evident by the fact that bearings when taken out for inspection after several years' continuous run are found to be subject to practically no wear. In several cases, the original tool marks upon the interior of the shell have been preserved.

The benefits resulting from the employment of a closed oil circulating system and large bearing areas are apparent in the cost of operating a turbine in regular service. As a result of inquiries in several concerns employing Westinghouse-Parsons turbine machinery, it has been elicited that a turbine ordinarily consumes about ¼ gallon of high-grade engine oil per KW. capacity per year; or, in other words, the total quantity of oil used per year averages about 100 gallons for a 400-KW. turbine. As this oil costs from 25 to 50 cts. a gallon, the expense for oil for the turbine is not ordinarily over 7½ to 12½ cts. a day, and even this is not all directly chargeable to the turbine, as it is common practice to utilize the oil which is removed from the circulating system on auxiliaries and other low-speed machinery.

It is well known that flexible bearings are employed on Parsons turbines of small sizes in order to permit the rotor to revolve about its gravity instead of its geometric axis, this being necessary at the high speeds employed in order to neutralize the effect of minute errors in the balancing of the disks. The flexible bearings consist of a nest of concentric bronze sleeves with sufficient clearance between them to permit the formation of oil films, which act as cushions, permitting a certain amount of vibration of the shaft, but at the same time restraining such vibration within narrow limits. In the larger sizes of turbines, however, and, in fact, for all machines running below 1,200 revolutions per minute, the flexible bearing is no longer found necessary, and is replaced by a solid split self-aligning journal, lined with antifriction metal, as in the ordinary forms of low-speed machinery.

TURBINE GENERATORS.

It is an interesting fact that, owing to the introduction of steam turbines, the general characteristics of generating apparatus have been modified to a wide extent, and in points of running speeds have returned to the practice of the first builders of electrical machinery. Owing to the restrictions placed upon the designers by reciprocating engine speeds, the dimensions and bulk of engine type generating machinery have, of late years, become enormously increased; similarly, the cost of construction. With the advent of the turbine, however, speeds have been increased to such a point as to secure in the generator construction minimum bulk and cost consistent with strength and durability.*

The turbine generator is more easily applied to alternating current work, for the reason that commutation difficulties involved in direct current machinery running at high speeds are avoided. The preferable construction, therefore, comprises rotating field and stationary armature. In present turbine generators the armature construction is not essentially different from that of the ordinary engine type machines. In the construction of the field, however, the centrifugal stresses necessitate a construction of greater inherent strength. Recent practice embraces two designs—one of built up form—used in fields having six or more poles, and the other of a solid steel casting thoroughly annealed, bored for the reception of the shaft, and slotted axially for the reception of bar or strap windings which are insulated and confined in position by wedges.

The turbine, however, makes possible the use of a still further type of generator, which, although presenting difficulties in design at ordinary engine speeds, becomes ideally suited for direct connection to the turbine, both by reason of its electrical characteristics and its inherent strength of mechanical construction. It is well known that, if the ordinary squirrel cage induction motor runs below synchronism with the system upon which it is operated, it will absorb power from that system proportionate to the slip or drop in speed. If it is run in synchronism therewith by external means, it will absorb no power; and if run above synchronism, it will become a generator and return electric power to the system.

When running below synchronism, the greater part of the current absorbed by the motor appears as power, but a small part is consumed within the motor itself in magnetizing its rotating field. When run above synchronism, the motor, now a generator, still requires magnetizing current from the line to which it is connected. It is, therefore, incapable of operating by itself, and must be run in connection with synchronous machinery capable of supplying its magnetizing current and controlling the frequency of the system.

The induction of non-synchronous generator, unfortunately, imposes a lagging current upon the supply system, but the power factor can be brought within a few per cent. of unity, so that the effect upon the system may be readily neutralized. Its peculiar electrical characteristics impose limitations upon its general use for power station work, but when employed in conjunction with synchronous apparatus, such as ordinary alternators, synchronous motors and rotary converters, it becomes peculiarly suitable for extension to a power system in which the limit of generator capacity has already been reached. With the apparatus mentioned, particularly with synchronous motors and rotary converters, a sufficient leading current may be impressed upon the system by overexciting the fields of these machines to entirely neutralize the effects of the magnetizing currents required by the induction generator, so that, in general, if existing apparatus is ample to care for existing inductive loads with reasonable margin, the induction generator can be employed to great advantage.

A feature which is particularly favorable in rendering it suitable for turbine driving is, that by largely reducing the number of poles the magnetizing currents may be largely reduced. For this reason, the limitations of the induction generator occur largely in the direction of bulk rather than otherwise. As it must operate at the comparatively high speed of the turbine, it is thus possible to reduce the number of poles to a few pairs, so that the losses above mentioned are minimized and the generator becomes commercially practicable. And as the squirrel cage construction of the rotor is peculiarly well-suited for high speed work, we are fortunate in having here one of the few cases in which the electrical and mechanical conditions governing generator and prime mover are almost exactly suited to each other. In general, the higher the speed at which the machines can be safely operated, the less the material necessary and the smaller the losses, resulting in an extraordinarily high efficiency and power factor.

For example, with a two-pole 60-cycle induction generator of 500 KW., running at 3,600 revolutions, the power factor may be brought as high as 98% or higher at full load, and the total efficiency will be far greater than that of present generating machinery.

ECONOMY.

From these curves and table of tests (not reprinted.—Ed.) may be gleaned a number of interesting facts which it may be worth while to point out here.

First.—The Willans line or curve of total water consumption is approximately a straight line at all points up to the opening of the secondary governor valve on heavy overloads. This relation has an immediate thermodynamic meaning and points to the utilization of steam in the turbine with the same internal efficiency at all loads; or, in other words, that the losses in the turbine from all causes, thermal, thermodynamic and mechanical, are approximately constant at all loads.

Second.—The necessity of high vacua and high superheat is not essential to high economy, as has been before alluded to. This is shown in tests of a 400 KW. turbine under 26-in. vacuum, 125 lbs. pressure and saturated steam. A water rate of 15.41 lbs. per B. H. P. was obtained, which, although not remarkable, would seem to bear out the supposition of small fluid frictional losses within the turbine. Another result of 14.4 lbs. steam per B. H. P. hour, obtained with a 1,250 KW. turbine operating with 150 lbs. boiler pressure and 25 ins. vacuum is of interest.

Third.—The gradual improvement in economy with an improvement in operating conditions is well brought out by the tests on the 1,250 KW. turbine. By increasing the vacuum from 27 ins. to 28 ins., and the temperature of the steam from that corresponding to dry saturation to 77° F. superheat, the full load steam consumption was reduced from 14.6 lbs. to 13.2 lbs. per E. H. P. hour.

FOUNDATIONS AND POWER PLANT DESIGNS.

With steam turbines, practically no foundations are necessary, merely something that will uphold the dead weight of the machine. Foundation bolts are never used except on shipboard. Operation of turbines on light flooring is entirely satisfactory, thus permitting their being placed on upper floors of buildings. This also permits of the condensing plant being located immediately below the turbine, by this means the total plant occupying the minimum amount of floor space.

It is presumable that surface condensers will be more frequently employed in connection with turbines than other types, if only because of the advantage of absolutely clean feed water. It is claimed by condenser builders that with modern dry vacuum pumps, and a closed hot well system, that a better vacuum can be obtained than with a jet condenser, due to the fact that the water does not become aërated. The cost of operating a surface condenser can, under favorable conditions, be kept very small, especially when the circulating water does not have to be raised to any height.

A jet condenser, on the other hand, has to do work in order to expel the cooling water against an atmospheric pressure, according to the vacuum, but is a considerably simpler piece of apparatus, is less costly and is generally not subject to electrolytic troubles that are sometimes incidental to surface condensers.

Barometric condensers make a very suitable type of condenser for large vertical engines, especially when the steam can get direct to the condenser without having to be carried upward. With turbines, in connection with this type of condenser, the author has observed that some work is required to carry the water in the exhaust steam to the top of the condenser. In one instance this was carefully observed in connection with a 1,500 KW. turbine. The exhaust left the turbine cylinder at the bottom by means of two elbows and about 6 ft. of horizontal pipe, passing up a vertical pipe to the condenser. Except on fairly heavy loads, the horizontal pipe had water in it, observed by a gage. The amount of this water may be said to have been a measure of the load. The back pressure due to this piece of pipe and two elbows, together with the water lying in the bottom, amounted to ⅝-in. mercury with steady load. If the load became less, the back pressure would disappear until more water collected in the pipe and the same ⅝-in. back pressure would be re-established. If, on the other hand, the load increased, this back pressure would rise sometimes to as high as 1-in., until the water could be carried away, when it would fall back again to about the same ⅝-in.

As turbines can expand down to the utmost limits of exhaust pressure—it is desirable to give the turbine every advantage in this respect—hence it is well to avoid carrying the exhaust up hill, thus giving the water that must necessarily exist in the exhaust, an opportunity to drain and keep the exhaust pipe free.

While the author has endeavored to point out that high vacuums are not necessary to the successful operation of steam turbines, the higher economy obtained with high vacuum warrants the condenser problem being carefully considered.

It has been shown by tests, that each inch of vacuum above 26 ins. will benefit the economy from 3% to 4%. Assuming a 1,500 KW. turbine, operated at full load for a day at 28 ins. vacuum instead of 26 ins. vacuum, it will save approximately 1 lb. of steam per HP. per hour, or 48,000 lbs. a day of 24 hours. If we allow for 1 lb. of coal costing $2 per ton, and evaporating 7 lbs. of water, this will mean a saving of 6,875 lbs. of coal, representing a daily saving of $6.87 or $2,061 a year. Thus the difference between the two condenser investments, being $1,000, would accordingly pay interest of about 50%, due to the saving in coal.

Such figures as these, however, are of no practical value, because of the time a power plant is running at fractional loads, but nevertheless, it is apparent that it is worth while to employ high-class condensers. A point, however, which should not be lost sight of is, that the higher vacuum gives a greater percentage gain in economy at fractional loads than at full loads.

In this matter must be considered also the extra cost of operating with a high vacuum.

With air leaks eliminated and a closed hot well system, the air pump should take no more power because of high vacuum. A dry air pump will obviously be doing no work beyond its own friction when there is no vacuum in the condenser. Similarly, it will be doing no work when there is a perfect vacuum in the condenser, provided there are no air leaks. It may be interesting to record that the maximum load when the air pump is started comes on when the vacuum is about 20 ins. to 21 ins.

With the circulating water pump, however, the matter is different, as it will have approximately two or three times as much water to handle, according to its inlet temperature, with the higher vacuum. The power required to do this varies in individual cases, but it often happens that the water can be returned to the same level from which it has been taken, such that the circulating water system forms a syphon, and the pump has only the fluid friction of the pipes and condenser tubes to overcome.

There are at present in operation and in course of erection in this contry in sizes ranging from 400 to 2,000 KW., 43 turbines of the Westinghouse-Parsons type, the total capacity of which approximates 27,000 KW. There are also under construction at East Pittsburg, in various sizes to a maximum capacity of 5,500 KW. turbines aggregating 69,400 KW. Thus the output of one builder, including machines in operation, reaches a total of 111 turbines, aggregating 96,400 KW. The foregoing record is convincing that the application of the steam turbine to general power work is permanently established.

*A pertinent comparison may be made in the two types of 5,000 KW. generators which will form the power equipment of the Rapid Transit Subway in New York City. The engine type generators run at 75 revolutions per minute, are approximately 40 ft. in diameter and weigh 980,000 lbs. The turbine generators, on the other hand, run at 750 revolutions per minute, are 12 ft. 6 ins. in diameter, and weigh 234,000 lbs., the weight of journals and shaft excluded in each case. The engine type generators have 40 poles, and the turbo-generators four, giving the same frequency—25 cycles per second.

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